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INDIVIDUALIZED SCIENCE INSTRUCTIONAL SYSTEM

HOUSEHOLD ENERGY

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INDIVIDUALIZED SCIENCE INSTRUCTIONAL SYSTEM

HOUSEHOLD ENERGY

ANNOTATED TEACHER'S EDITION

Ginn and Company

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Learning about energy has become desirable and practical with the onset of energy shortages. *Household Energy* might be considered an operational definition of energy. The traditional definition of energy, "the capacity to do work," is limited since the concept of energy is too complex to be pinned down with a few words. In this minicourse, energy is studied, handled, and understood in terms of everyday household use. Using conversion factors, students compare different kinds of energy and investigate the loss when converting from electrical energy to heat energy. Students learn to read meters, calculate electric bills, and save fuel. They find out how refrigerators, air conditioners, heating systems, and thermostats work.

Household Energy emphasizes the cost involved in energy transformations. Energy is something we must buy. We use it in various ways and then discard most of it in the form of heat. Students have a personal concern with money, whether it comes from their pockets or is the subject of family discussions. The size of a unit of energy is one way to make energy tangible in a quantitative way. The cost per unit is sometimes easier to visualize.



Household Energy contains eighteen activities, nine in the core section, five in the advanced section, and four in the excursion section. Except for the planning activities and Activity II, the activities in each section may be done in any order.

The core activities acquaint the student with the routine terms and skills useful in the proper management of household economics. Students relate the sources of electrical energy to the cost of operating household appliances by reading electric meters, power ratings on appliances, and calculating an electric bill. The convenience and efficiency of fuels are compared and energy conserving suggestions, such as insulation, are made for home heating and cooling systems. Thermostats are investigated as feedback control mechanisms.

Heat energy is examined historically and quantitatively in the advanced activities. The contributions of Joule, Mayer, Rumford, and Davy to the understanding of heat are described. Joules, watts, kilowatt hours, and calories are compared mathematically and experimentally. Heat transfer is explained using the kinetic molecular theory.

In the excursion activities, solar energy as an alternative energy source is explored, as well as the greenhouse effect and ways to save money in the operation of hot-water heaters, refrigerators, and stoves.

Materials and Equipment

The following chart represents an estimate of needs based on "student units." The student unit may be one student working alone, two students working as partners, or several students working as a group. The size of the student unit will depend on the nature of the activity and on the availability of materials and equipment.

QUANTITY PER STUDENT UNIT	ITEMS	ACTIVITIES			NO. UNITS THAT CAN SHARE
		Core	Advanced	Excursion	
	Consumable				
10 cm × 3 cm	Foil, aluminum			16	
3	Matches	7		16	
10 cm × 12 cm	Paper or cardboard			16	
10 cm × 10 cm	Plastic wrap			18	
1 inch	Tape, adhesive, or grease pencil			17	
	Nonconsumable				
1	Ammeter, DC 0–5 A or 0–10 A	3			5
1	Beaker, 250-ml	9	12		3
1	Bimetal strip	7			3
1	Burner, Bunsen		13		3
1	Candle			16	5
1	Cup or can holder, plastic foam		12		12
1	Cup or can, metal, size of 250-ml beaker	9			3
1	Cup, plastic foam, size of 250-ml beaker	9		18	3
1	Dry cell, 1.5 V	3			5
1	Graduated cylinder, 100-ml		12		12
1	†Heater, immersion, 75–150 W, 110 V		12		12
1	Lamp bulb, 1.5 V	3			5
1	Lamp socket	3			5
5	Leads, electrical	3			5
1	Metre stick	7			3
1	Mirror, concave			16	3
1	Pan, large	9			3
2	Pieces, plastic foam, 10 cm × 10 cm	9			3
1	Rod, glass, 10–15 cm		13		5

†For alternative setup and materials, see "Activity 12 Alternative" under Advance Preparation on page TM 6.

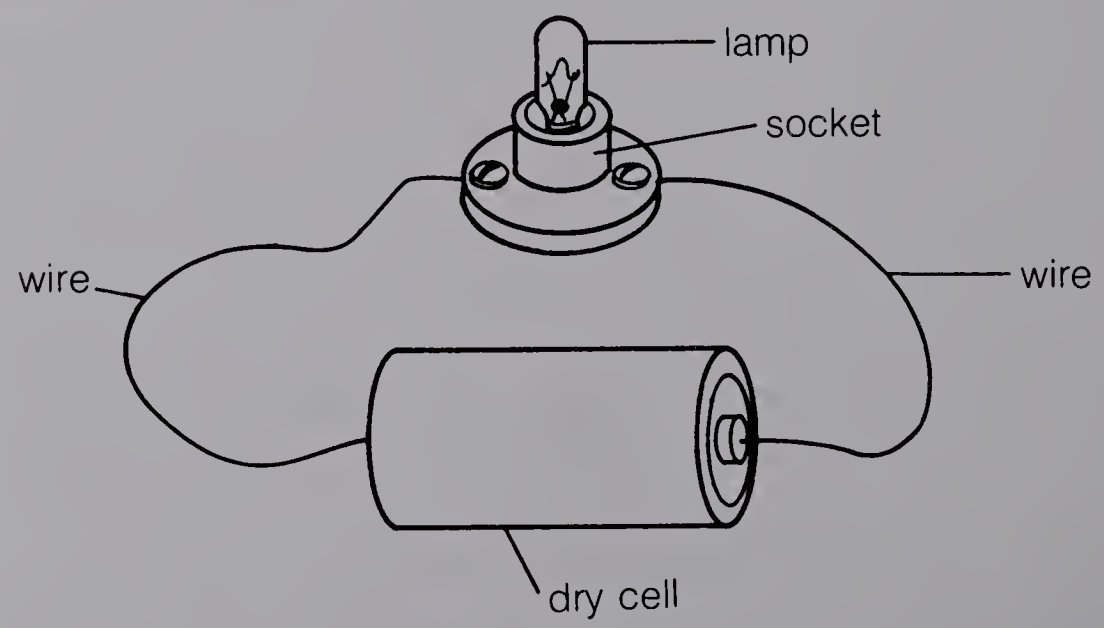
Materials and Equipment (continued)

QUANTITY PER STUDENT UNIT	ITEMS	ACTIVITIES			NO. UNITS THAT CAN SHARE
		Core	Advanced	Excursion	
	Nonconsumable				
1	Rod, metal, 10–15 cm		13		5
1	Rubber band	7			3
1	Safety goggles		13		1
1	Saucepan, 15 cm diameter			17	5
1	Test tube, 20 × 175 mm		13		1
3	Thermometers, Celsius, 0–110°	9	12	16,18	3
1	Towel, paper or cloth	9			3
1	Tweezers			16	3
1	Voltmeter, DC, 0–5 V or 0–10 V	3			5
1	Watch with second hand, or stopwatch	9	12	17	3
1	*Resource Unit 5*		12		6
1	*Resource Unit 13*	7			6
1	*Resource Unit 14*	9			6
1	*Resource Unit 17*		13		6



Activity 3 Core Page 10

Be sure the dry cells are fully charged. You can check them by connecting a 3-volt lamp to each in turn. The lamp should glow with a yellow white light. If the light glows red or there is no light, replace the cell.



Activity 4 Core Page 18

You may want to contact your local electric company for an electric meter or model that shows how the gears work the pointers on the dials. The public relations division may also have some booklets that you might find useful.

Activity 5 Core Page 23

Get copies of your community's sliding rate charge and fuel adjustment charge before students begin this activity.

Activity 6 Core Page 27

You may wish to inquire about the cost of various fuels in your area before students begin this activity.

Activity 7 Core Page 32

Remove the thermostat from a broken appliance and open it to expose the bimetal strip. Bimetal strips are also used in dial thermometers. The strip is bent into a thin coil (Figure 1). Changes in temperature cause the strip to turn or twist, and as the strip twists it turns a pointer that indicates the temperature on the dial.

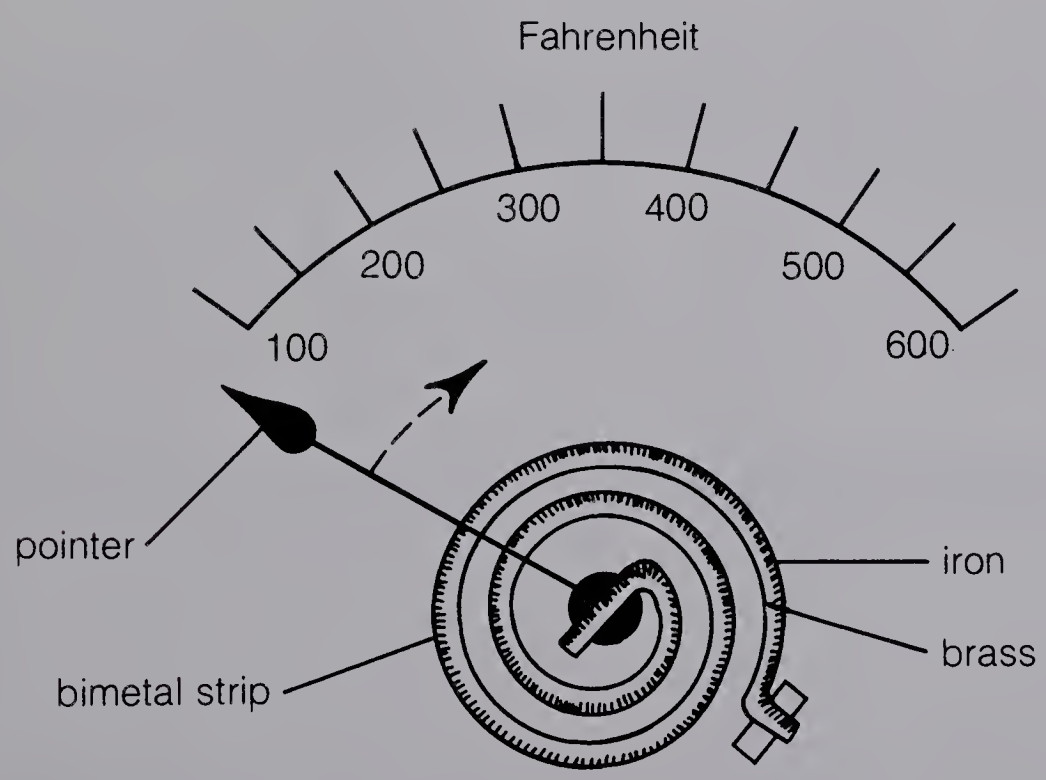


Figure 1

Activity 12 Alternative

Here is an alternative method for the investigation in this activity. Each student unit will need the following:

2 copper leads, enameled, fine, 10-cm
resistor, 2-ohm, or 20 cm of nichrome wire, 22-gauge
drinking straw, plastic
rod, glass, 3 mm diameter
test tube, small
graduated cylinder, 0–10 ml
5 electrical leads
DC ammeter, 0–5 A
DC voltmeter, 0–5 A
dry cell, 1.5 V
thermometer, Celsius, 0–110°
watch with second hand

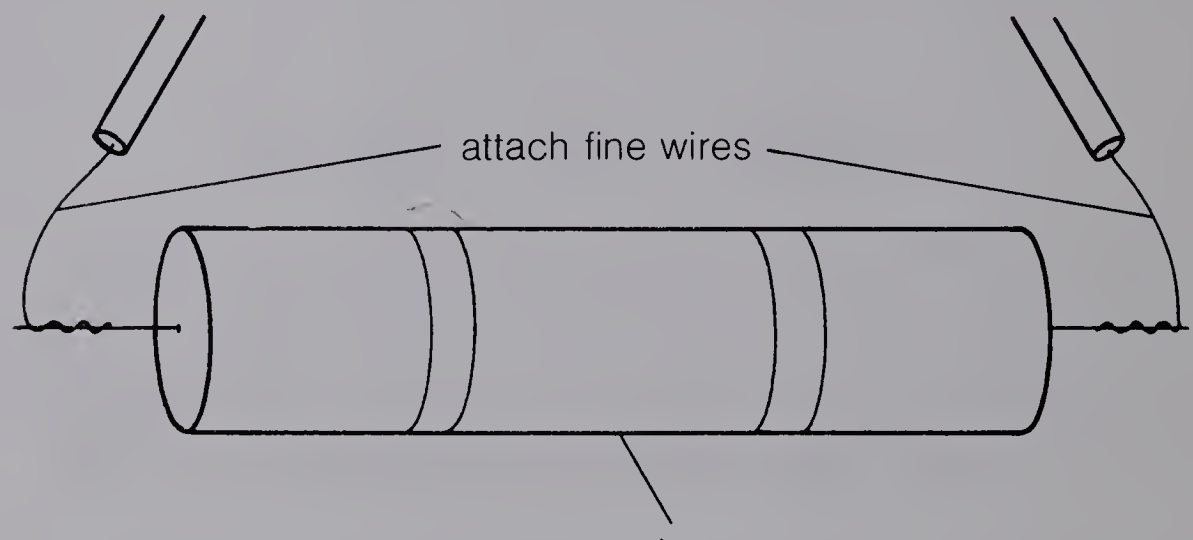


Figure 2

Attach the two copper wires to the resistor as in Figure 2. Slip the drinking straw over the leads as in Figure 3. This allows you to control the placement of the "heater."

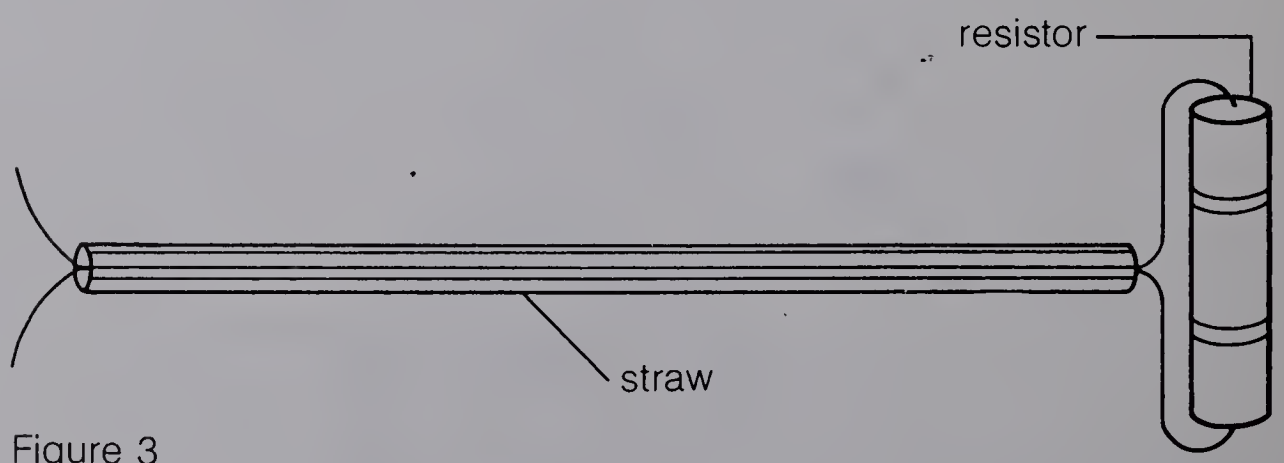


Figure 3

If you do not have a 2-ohm resistor, wrap nichrome wire around a glass rod 10 times. See Figure 4. Remove the rod, attach the

copper wires as in Figure 2, and insert into the drinking straw as in Figure 3.

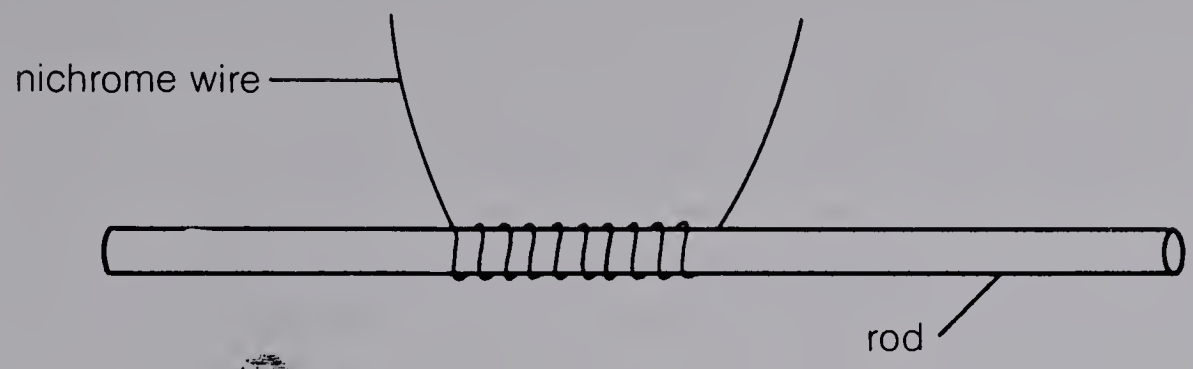


Figure 4

Put the resistor or wire coil into a test tube, measure water to cover the coil, and add to the test tube. Connect the ammeter in series with the heater and dry cell, and connect the voltmeter in parallel (Figure 5). Put the thermometer into the water so that it does not touch the heater. Proceed with the measurements as directed in the activity.

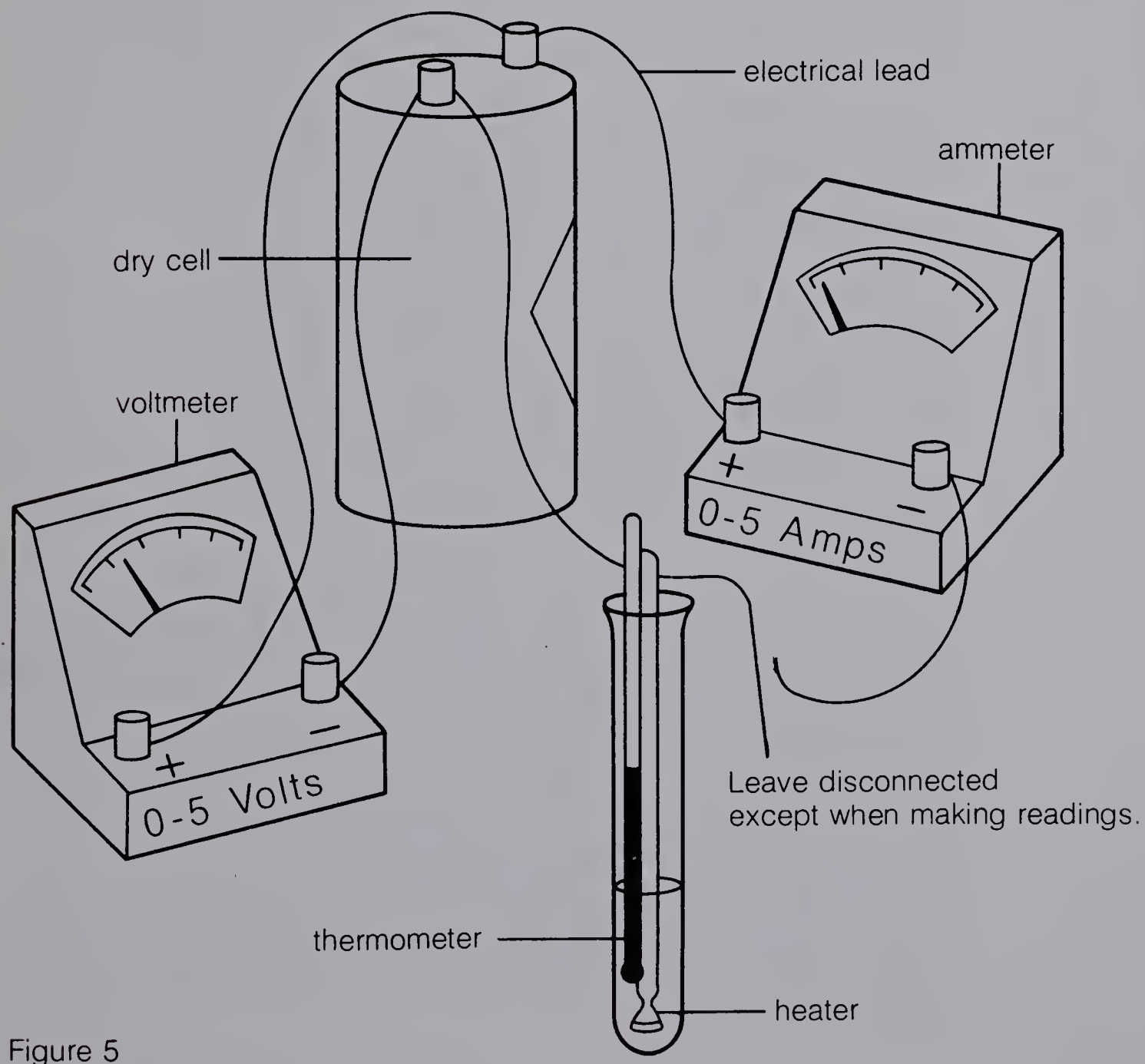
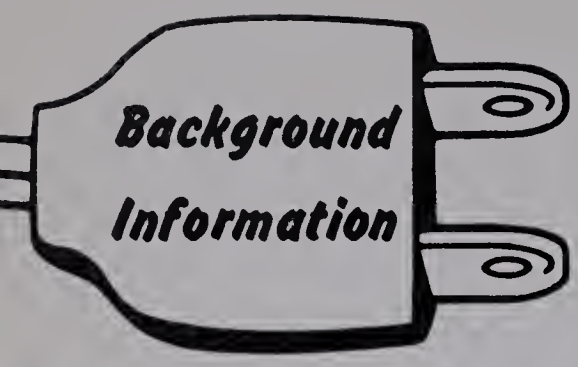


Figure 5



All the power used in our homes comes from stored energy reserves. Some of this energy is stored mechanical energy, such as water and wind. Water power is one of the world's oldest energy sources and remains a significant source of potential mechanical energy. It is harnessed primarily by damming natural waterways and then using the resulting height of the water to operate hydraulic turbines for producing electricity. At present about 16 percent of the electrical power generated in the United States is produced in this way, and it probably will not be expanded much in the future.

The use of windmills declined rapidly after World War I with the development of the internal combustion engine and the spread of electrical power. Now there is renewed interest in wind power as the search for alternative sources of energy spreads. Today about fifty projects to investigate various ways to harness wind power are supported by federal funds.

By far the most important source of stored energy is the chemical energy in the so-called fossil fuels. These are the coal, oil, and gas that were formed by heat and pressure from thick deposits of organic materials millions of years ago. In effect they are stored energy from the sun. Combustion releases this energy in the form of heat. These fossil fuel deposits once seemed endless; today we know they are finite. Yet they are being used at ever increasing rates. About 80 percent of all electrical power produced in the United States comes from fossil fuels.

People in the United States can no longer depend on any single resource for the bulk of their energy, as they have periodically throughout their history—first with wood, later with coal, and today with oil, as shown in Figure 6. The development of synthetic fuels is embryonic and the expansion of nuclear-power output is slowed by unresolved environmental and safety concerns while the bottom of the barrel is being reached for fossil fuels. Here's the picture.

Natural Gas: The cheapest, most convenient, and cleanest of the fossil fuels, gas provides about a third of the country's total energy and a quarter of its electricity. But the domestic reserves are being used faster than new ones are found. A frantic scramble is under way for new sources and substitutes, such as the gasification of coal. But such substitutes cost several times as much as domestically produced natural gas, and the price for newly discovered domestic gas has jumped markedly.

Oil: Supplies of this fuel are only slightly better than those for gas. Forecasts indicate that the world oil reserves will last for only about a hundred years, and reserves in the United States may be exhausted before that.

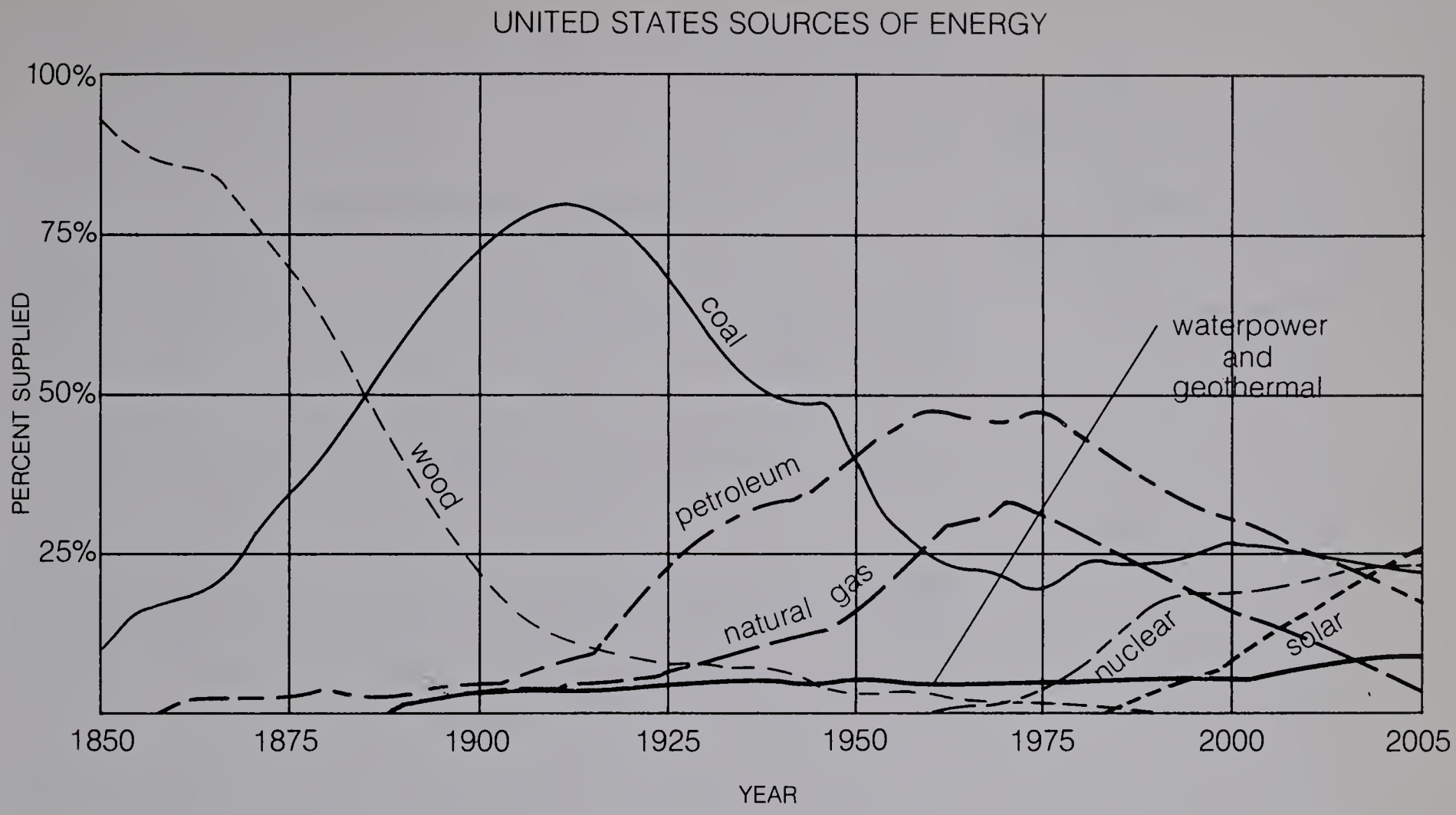


Figure 6

Wells in the United States, not including the wells in Alaska, are pumping oil at capacity and they cannot meet the demand. About a third of our petroleum comes from other countries, and, according to estimates of the Natural Petroleum Council, by the early 1980's it will be about half.

Coal: This is by far the most abundant fossil fuel. Reserves in the United States amount to about 1.5 trillion tons. This substantial reserve should last for hundreds of years, but coal offers special problems. It is the worst offender for producing sulfur compounds that are turned into acid when mixed with moisture in the atmosphere. Also, mining coal without doing irreparable damage to the environment has become a real challenge.

We must face the fact that fossil fuels are a diminishing reserve and look to other sources of energy. Nuclear energy, solar energy, and geothermal energy are sources for the production of electricity. The demand for electricity is still growing and the utility industry may become the single largest consumer of energy. But large concentrations of thermal energy need not be used exclusively to generate electricity; some believe that, in time, hydrogen will be produced from water by thermal catalytic or electrolytic methods at commercially attractive costs. Hydrogen may eventually become an alternative to electricity as a secondary form of energy.



In addition to the Minicourse Test, you may wish to use some or all of the following suggestions as part of your evaluation.

Essay Questions

These three essay questions and possible answers are related to the core activities.

1. Describe two ways to find how much electricity is used in your home for a twenty-four hour period. Include the data you'd collect and how you would use it, and the energy units used.

Answer: An easy way to find the amount of electricity used would be to read the electric meter before and after the twenty-four hour period. The difference between the two numbers would equal the kilowatt hours of electricity used.

A more difficult way would be to determine the number of hours or parts of hours each appliance was on during the twenty-four hour period. Then, find the voltage and amperage ratings for all the appliances, making guesses where necessary. For each appliance, multiply the volts by the amperes and then by the number of hours the appliance had been on. Add the watt hours for all the appliances and divide by 1000. This would be the number of kilowatt hours of electricity that had been used.

2. List ten ways to reduce the total energy used in a home.

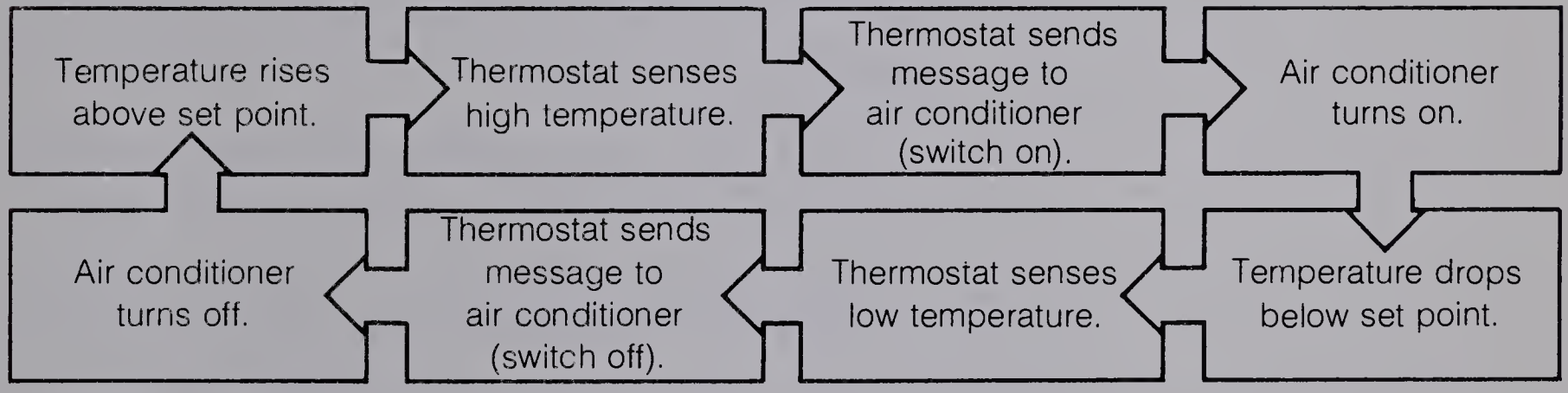
Answer: The following are some of the possible answers.

a. Increase or improve the insulation.
b. Set the thermostat of the heating system as near as possible to the outside temperature.
c. When practical, use fluorescent rather than filament bulbs.
d. Rather than using several small bulbs, use one large bulb that gives off the same amount of light as the group of small bulbs.
e. When buying an electrical appliance, choose the one with the lowest wattage that will still do the job.
f. Put the hot-water heater nearest the hot-water faucet that is used most.
g. Use cold water rather than hot water whenever possible.
h. Schedule baths close together.
i. Set the thermostat of the hot-water system as low as practical.
j. Repair leaky faucets immediately.

k. Be sure the seals around refrigerator and freezer doors are in good condition.
l. Locate the refrigerator away from direct sunlight and heating appliances.
m. Set the thermostat of the refrigerator as high as practical.
n. Close the refrigerator door as soon as possible.
o. When cooking, use the smallest element that will do the job.
p. For small jobs, use a small appliance instead of a large one.
q. Turn down the element on a stove when a liquid nears boiling.

3. In a short paragraph, or diagram, explain how an air conditioner works as a feedback system.

Answer: An air conditioner is a feedback system because it switches on and shuts off automatically as the room temperature changes. The temperature of the room is the feedback for the thermostat. When the preset temperature is reached, the electrical circuit is broken and the air conditioner shuts off. When the air in the room warms up enough, the electrical circuit is completed and the air conditioner starts automatically.

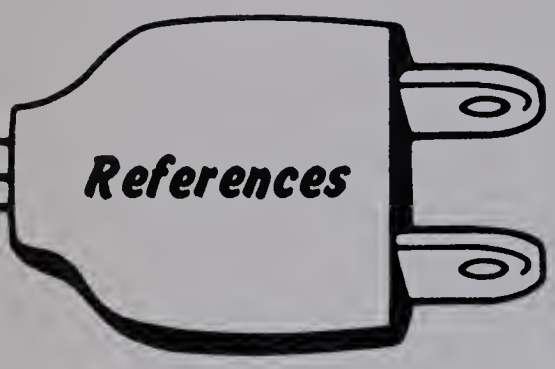


Laboratory Performance

The following items, which are related to core material, require students to demonstrate a skill. The materials will need to be prepared in advance. You may wish to assess students soon after they have learned the skill.

1. Draw a set of dials (without pointers) to represent a home electric meter. Draw in the pointers just before asking, "What is the reading on the electric meter?" Vary the location of the pointers for each student.

2. Paste pictures of various appliances on 3 inch × 5 inch cards. Indicate the wattage of the appliance. Write a question such as, "What is the cost of using this appliance for one hour if the electrical energy costs 3¢ per kilowatt hour?"



Science 184:245–389. 1974.

The entire issue is develoted to energy. The articles are relevant to important public decisions and are organized under Impact of the Crisis, Policy, Economics, The Developed Technology, and Developing Technology.

Farber, Erich A. 1972. *Solar energy conversion: systems design.* Brooklyn, New York 11201: Presstech Design, Inc., 235 Duffield Street.

A variety of machines that have been adapted to solar energy are explained and illustrated in this book. It is also available as a reprint from Solar Energy and Energy Conversion Laboratory, University of Florida, Gainesville, Florida 32601.

Fowler, John M. October 1975. Entering a new science age. *The Science Teacher* 42:32–38.

This is a reprint with slight adaptation from Volume I of the *Energy-Environment Source Book,* recently published by NSTA.

General Electric Company. *Watts going on where you live?* Pub. No. ENG-1 (Rev. 1). P.O. Box 500, New Concord, Ohio: General Electric Company.

Hints on how to save money when operating common household appliances are presented in an attractive manner in this pamphlet.

Hamilton, Roger. December 1975. Can we harness the wind? *National Geographic* 148:812–29.

New ways to harness the power our forefathers used is the topic of this article on the search for more energy for homes.

The following pamphlets are useful references. They are available at low cost from the Superintendent of Documents, U.S. Government Printing Office, Washington, D.C. 20402, or from Consumer Product Information, Public Documents Distribution Center, Pueblo, Colorado 81009.

Eleven ways to reduce energy consumption and increase comfort in household cooling. 0303-0876.

This pamphlet presents useful guidelines for increasing the efficiency of home cooling systems.

Seven ways to reduce fuel consumption in household heating . . . through energy conservation. 0303-01086.

This simply illustrated pamphlet presents straightforward means of saving heat energy.

Checking your utility bills. 183D.

This pamphlet explains how to read gas and electric meters, calculate utility costs, and understand billing methods and forms.

Planning home improvement for energy conservation. 184D.

Cost estimates are included in these directions on how to design the best combination of insulation, storm doors and windows, weather stripping, and caulking to maximize savings in home heating and cooling.

Save energy, save money. 185D.

Simple do-it-yourself projects to insulate your home to get the most heat from furnaces, stoves, and fireplaces, and to use available heat from the sun are described in this pamphlet.

Tips for energy savers. 186D.

Additional hints for conserving energy in household heating, cooling, and appliance use are listed in this pamphlet.

Shuttleworth, Dorothy E. 1974. *Disappearing energy*. New York: Doubleday & Company, Inc.

This resource book presents data on the use and misuse of energy, as well as how energy-producing fields of coal, oil, and other fuels are searched for.

Weaver, Kenneth F. November 1972. The search for tomorrow's power. *National Geographic* 142:650–81.

This article describes the wide variety of power sources and possible ways to harness them that are being investigated in the search for new ways to fuel the future.

Wilhelm, John L. March 1976. Solar energy, the ultimate power house. *National Geographic* 149:381–97.

The efforts of scientists to fulfill an ancient dream by capturing the limitless power of the sun are documented in this article.

Williams, Richard J. 1974. *Solar energy technology and applications*. Ann Arbor, Michigan: Ann Arbor Science Publishers, Inc.

This nontechnical book surveys the technology and applications of solar energy. Common techniques developed or postulated for concentrating solar energy are described and comparisons made between solar energy and alternative energy sources.

Wilson, Mitchell. 1970. *Energy*. Life Science Library. New York: Time-Life Books.

More information concerning the lives and contributions of Joule, Mayer, Davy, and Rumford is presented. Sources of energy, the various forms of energy, and heat transfer are also included in this well-illustrated presentation of energy.

Young, Gordon. August 1975. Will coal be tomorrow's "black gold"? *National Geographic* 148:234–59.

The fuel scorned for oil looks better and better as oil prices go up. The past, present, and future costs are described in this article.

The following books are from the Science Study Series and prepared under the direction of the Physical Science Study Committee of Education Development Center, Newton, Massachusetts.

Brown, Sanborn C. 1962. *Count Rumford: physicist extraordinary*. Garden City, New York: Doubleday & Company, Inc.

This biography tells the story of Rumford's dual personality and exciting career in the fashionable worlds of London, Paris, and Munich and explores his contributions to science and technology, ranging from heat theory to the perfection of the fireplace and the drip coffeepot.

Sandfort, John F. 1962. *Heat engines: thermodynamics in theory and practice*. Garden City, New York: Doubleday & Company, Inc.

The concept of heat is developed in terms of history, people, and the machines around which our lives are organized. The main purpose of the book is to give the reader at least an elementary understanding of the first and second laws of thermodynamics, the significance of temperature, and the principle of the reversible heat engine. Background material for teachers and students with good reading ability.

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HOUSEHOLD ENERGY

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FOREWORD

Evidence has been mounting that something is missing from secondary science teaching. More and more, students are rejecting science courses and turning to subjects that they consider to be more practical or significant. Numerous high school science teachers have concluded that what they are now teaching is appropriate for only a limited number of their students.

As their concern has mounted, many science teachers have tried to find instructional materials that encompass more appropriate content and that allow them to work individually with students who have different needs and talents. For the most part, this search has been frustrating because presently such materials are difficult, if not impossible, to find.

The Individualized Science Instructional System (ISIS) project was organized to produce an alternative for those teachers who are dissatisfied with current secondary science textbooks. Consequently, the content of the ISIS materials is unconventional as is the individualized teaching method that is built into them. In contrast with many current science texts which aim to "cover science," ISIS has tried to be selective and to limit our coverage to the topics that we judge will be most useful to today's students.

Obviously the needs and problems of individual schools and students vary widely. To accommodate the differences, ISIS decided against producing tightly structured, pre-sequenced textbooks. Instead, we are generating short, self-contained modules that cover a wide range of topics. The modules can be clustered into many types of courses, and we hope that teachers and administrators will utilize this flexibility to tailor-make curricula that are responsive to local needs and conditions.

ISIS is a cooperative effort involving many individuals and agencies. More than 75 scientists and educators have helped to generate the materials, and hundreds of teachers and thousands of students have been involved in the project's nationwide testing program. All of the ISIS endeavors have been supported by generous grants from the National Science Foundation. We hope that ISIS users will conclude that these large investments of time, money, and effort have been worthwhile.

Ernest Burkman
ISIS Project
Tallahassee, Florida

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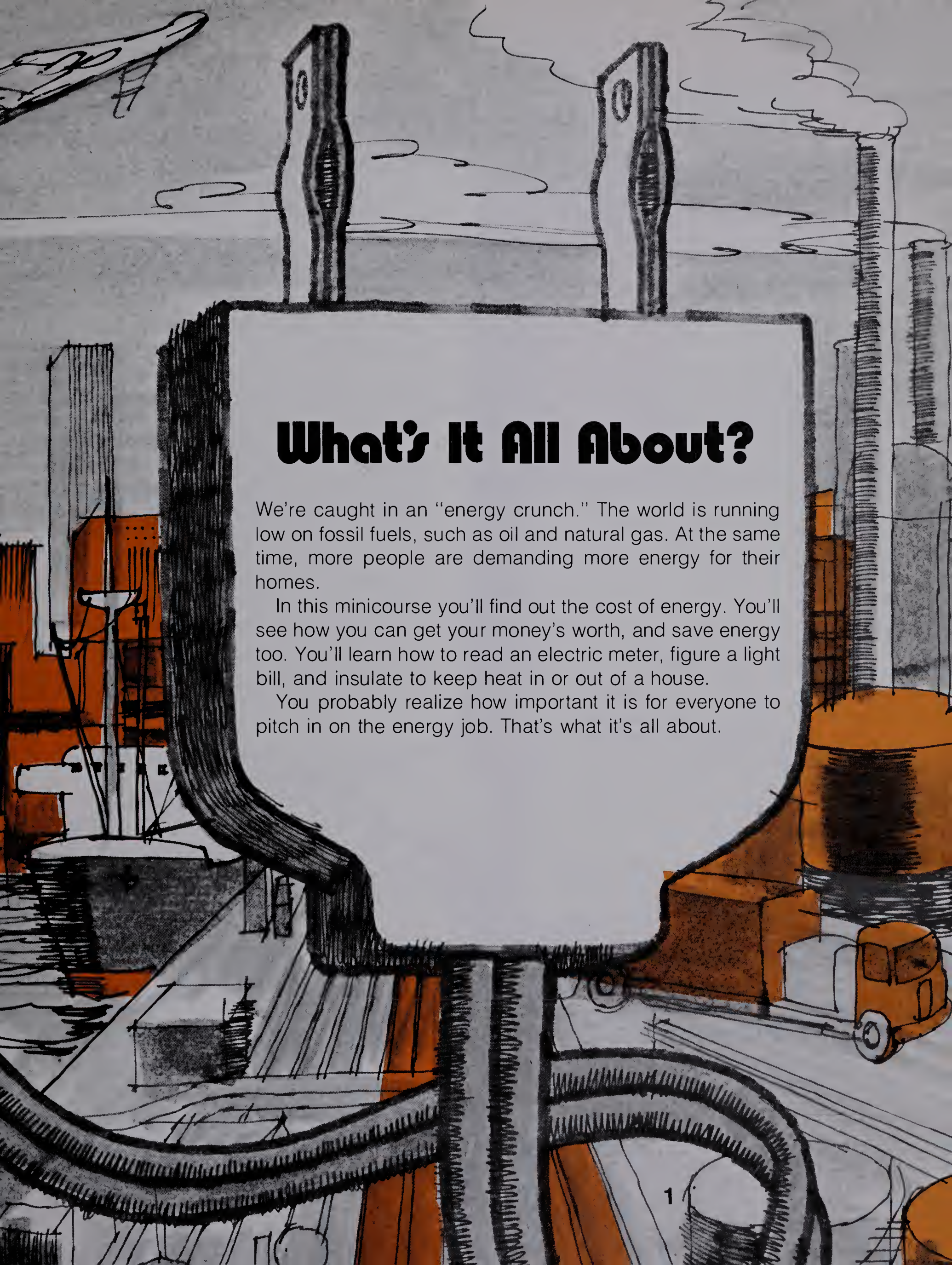
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What's It All About?

We're caught in an "energy crunch." The world is running low on fossil fuels, such as oil and natural gas. At the same time, more people are demanding more energy for their homes.

In this minicourse you'll find out the cost of energy. You'll see how you can get your money's worth, and save energy too. You'll learn how to read an electric meter, figure a light bill, and insulate to keep heat in or out of a house.

You probably realize how important it is for everyone to pitch in on the energy job. That's what it's all about.

core

Activity | Planning

Activity 2 Page 5

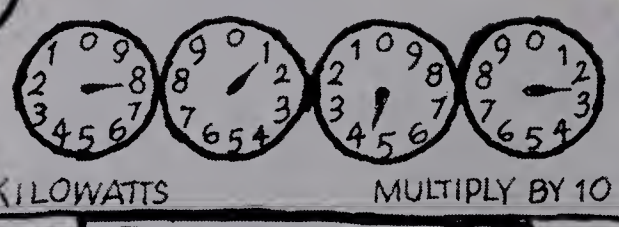
Objective 1: Define kilowatt hour and British thermal unit in terms of doing household tasks.
Sample Question: How much energy does a 500-watt washing machine use in 2 hours?

Objective 2: Define watt in terms of how fast energy is used by household electrical appliances.
Sample Question: The number of watts printed on an appliance means
a. the rate at which the appliance uses energy.
b. the voltage that must be supplied to the appliance.
c. the heat the appliance gives off.

Activity 3 Page 10

Objective 3: Compare the power used by different household devices.
Sample Question: When you are doing the washing, which uses energy faster, the electric washing machine or the electric hot-water heater that heats water for the washing?

Objective 4: Describe methods for conserving energy by decreasing the use of household devices.
Sample Question: Which would not conserve energy?
a. taking cooler showers or baths
b. skipping the drying cycle on the dishwasher
c. using the electric clothes dryer on pleasant days



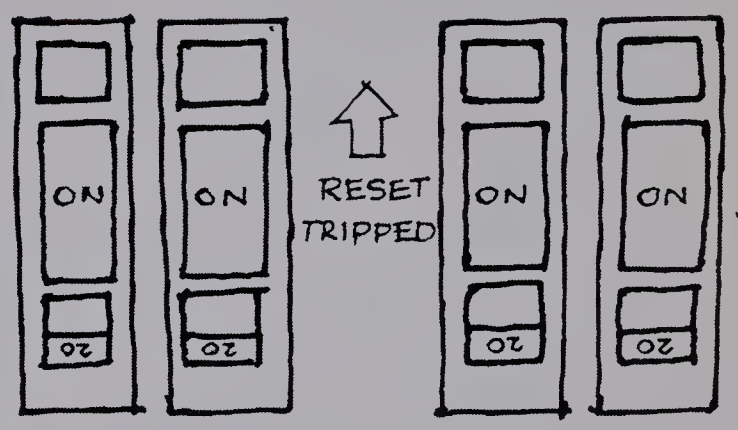
Activity 4 Page 18

Objective 5: Describe how to read a meter that measures electric energy consumption.
Sample Question: What is the meter reading in kilowatt hours as indicated by the dials?

Activity 5 Page 23

Objective 6: Describe how electrical energy for the home is measured and priced.
Sample Question: The "sliding rate" electric companies use means that
a. all kilowatt hours cost the same.
b. you pay less per kilowatt hour as amount used goes up.
c. the rate "slides" in amount from month to month.

Objective 7: Read a meter and calculate the electrical energy used and its cost.
Sample Question: Suppose a household used 864 kW h of electricity in a month. Using the rates given below, what would be the monthly bill?
First 30 kW h per month—
6.0¢ per kilowatt hour
Next 70 kW h per month—
5.3¢ per kilowatt hour
Next 200 kW h per month—
3.0¢ per kilowatt hour
Over 300 kW h per month—
2.5¢ per kilowatt hour



Activity 6 Page 27

Objective 8: Name the principal home heating methods and compare their efficiency and cost.
Sample Question: What are four common sources of energy for home heating?

Answers
1. 1 kW h 2. a 3. hot-water heater 4. c 5. 8142 kW h 6. b 7. $25.61 8. fuel oil, natural gas, electricity, and coal

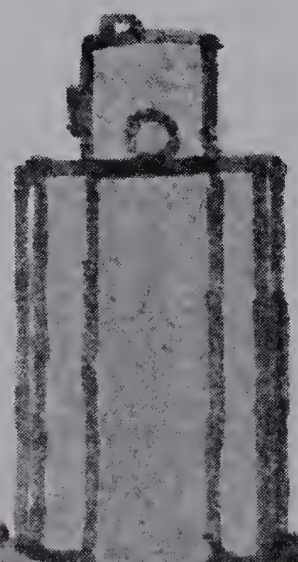
Activity 7 Page 32

Objective 9: Explain how feedback control is used by a thermostat to maintain an even home temperature.
Sample Question: In a home heating system, what happens when the thermostat senses too high a temperature?

a. *The switch closes, turning on the furnace.*
b. *The switch opens, turning off the furnace.*
c. *The switch opens, turning on the furnace.*

Objective 10: Describe how human comfort and energy consumption are related.
Sample Question: How is human comfort usually related to energy consumption?

a. *More comfort requires more energy consumption.*
b. *Less comfort requires more energy consumption.*
c. *There is no relation.*



Activity 8 Page 36

Objective 11: Describe how air conditioners and refrigerators work.
Sample Question: In what condition is a refrigerant when it leaves the compressor in an air conditioner?

a. *cold*
b. *solid*
c. *hot*

Activity 9 Page 39

Objective 12: Describe the benefits of insulating a house and the materials that make good insulators.
Sample Question: Which of the following could result from insulating your home?

a. *lower fuel bills*
b. *added comfort*
c. *higher energy consumption*

Answers
9. b 10. a 11. c 12. a and b

ACTIVITY EMPHASIS: Heat energy, mechanical energy, light energy, electrical energy, and chemical energy compared for equivalence.

Using Energy

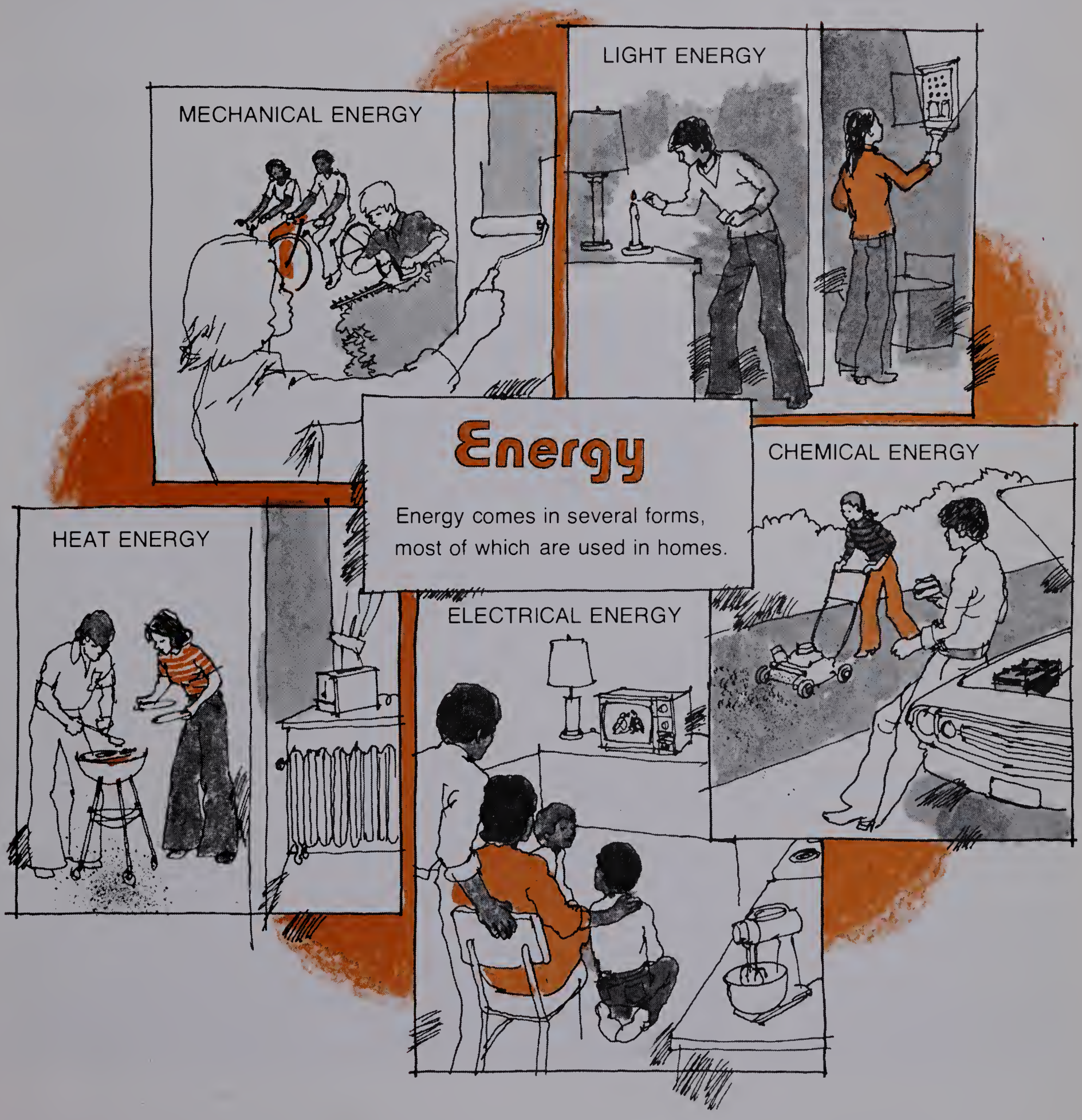


MATERIALS PER STUDENT UNIT

None.

The day is gone when you could only talk about energy. Now's the time to learn what energy is and about how it's used, measured, and priced.

Energy comes in several forms, most of which are used in homes.



2-1. Some of the electrical energy is converted into light energy.

2-2. Heat energy.

2-3. Chemical energy and light energy.

✔ 2–1. On page 5, why is there a lamp shown with both light energy and electrical energy?

✔ 2–2. On page 5, a lamp could be shown with what other form of energy?

✔ 2–3. What other forms of energy besides heat are involved in burning charcoal in a grill?

When the electric, fuel oil, and natural gas companies send out their bills, they're charging for energy. You pay for energy when you fill the tank at a gasoline station or buy groceries.

How do food stores and electric, fuel oil, and natural gas companies measure the energy you buy? It turns out that each measures energy differently.

Electrical Energy



Huge amounts of electrical energy are used in every community.

A meter in your home tells you how many *kilowatt hours* (kW h) of electrical energy your family uses. The watt is a unit that tells *how fast* electrical energy is used. *Kilo* means 1000, so a kilowatt hour is 1000 watts used for one hour, or

$$\text{kW h} = \frac{\text{watts} \times \text{hours}}{1000}$$

2–4. How many kilowatt hours are used by a 1000-watt electric heater in one hour? 2-4. 1 kW h

2–5. If a 100-watt light bulb burns for 10 hours, how many kilowatt hours are used? 2-5. 1 kW h

2–6. In 2½ hours how many kilowatt hours are used by a 400-watt electric iron? 2-6. 1 kW h

★ **2–7. According to the labels in Figure 2–1, which appliance uses energy faster?** 2-7. Electric motor.

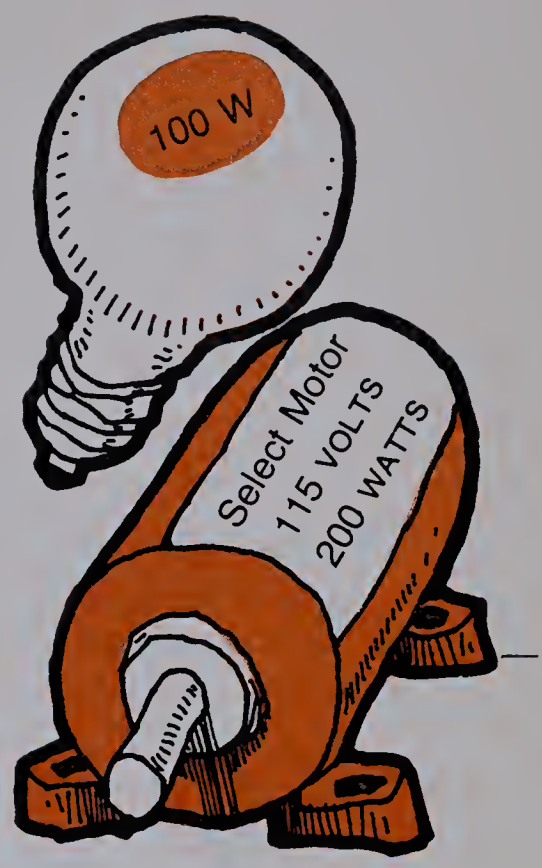


Figure 2–1

Energy from Fuel Oil and Natural Gas

The energy in natural gas and fuel oil is measured in British thermal units (Btu). A Btu is a unit for measuring heat energy.



Fuel oil is measured by the gallon.



Natural gas is measured by the cubic foot.

A gallon of fuel oil releases about 137,000 Btu of heat energy when it burns. About 950 Btu of heat energy can be gotten from a cubic foot of natural gas in some localities.

2-8. Heat energy.

★ **2–8. What kind of energy is commonly measured in British thermal units?**

Food Energy



A *calorie* is another unit for measuring heat energy. Food energy is usually measured in *kilocalories,* or *Calories* (with a capital C). A Calorie is 1000 regular calories. Sometimes Calories are called *diet calories*.

Kilowatt hours are pretty big chunks of energy. And the energy in a gallon of fuel oil or a cubic foot of natural gas is a big number of British thermal units. So that you can compare different kinds of energy, here are some small amounts that are all the same.

MECHANICAL ENERGY

The amount of energy used to lift a thick textbook one metre



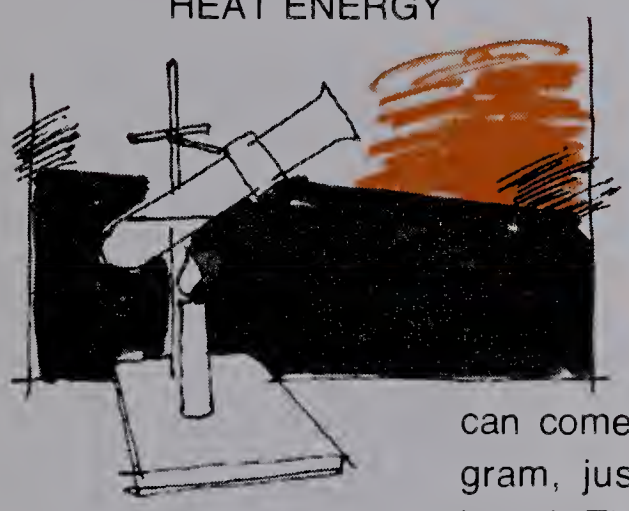
can also light the bulb of a two-cell flashlight for 10 seconds. A 100-watt bulb uses energy about 100 times as fast.

LIGHT ENERGY



can also raise the temperature of one millilitre of water 2½°C.

HEAT ENERGY

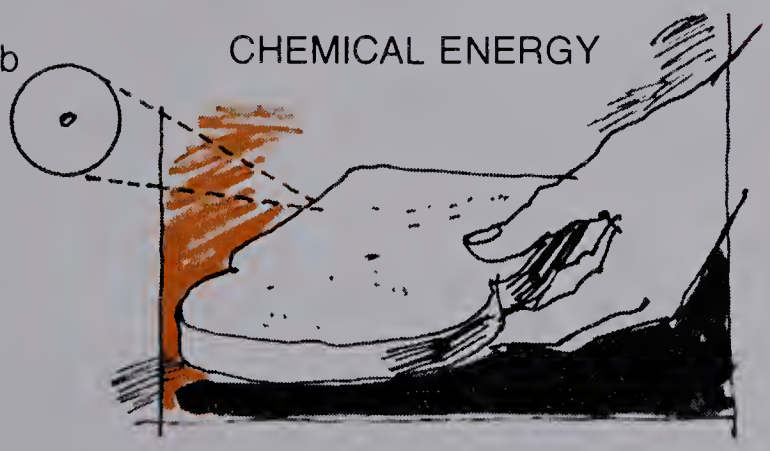


can run the average electric clock for five seconds. In an hour the clock would use over 700 times as much energy.

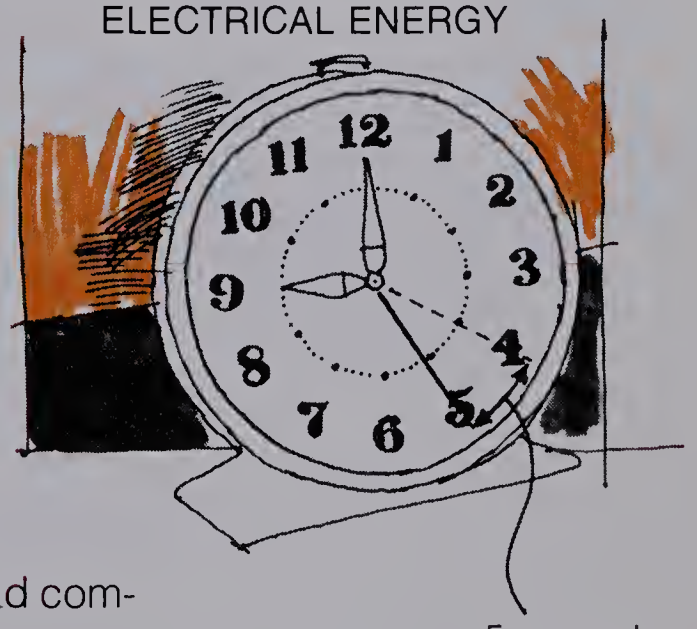
can come from eating one milligram, just one little crumb, of bread. The whole slice contains 25,000 times as much energy.

1 crumb

CHEMICAL ENERGY



ELECTRICAL ENERGY



5 seconds

2–9. How does the amount of energy in a slice of bread compare with that used by an electric clock in a day?

2-9. There is more energy in the slice of bread.

2–10. Would the amount of energy used by a 100-watt light bulb in 10 seconds be enough to raise the temperature of one millilitre of water from 0°C to 100°C?

2-10. Yes

ACTIVITY EMPHASIS: The amount of electrical energy used by all electrical appliances is estimated by interpreting their power rating.

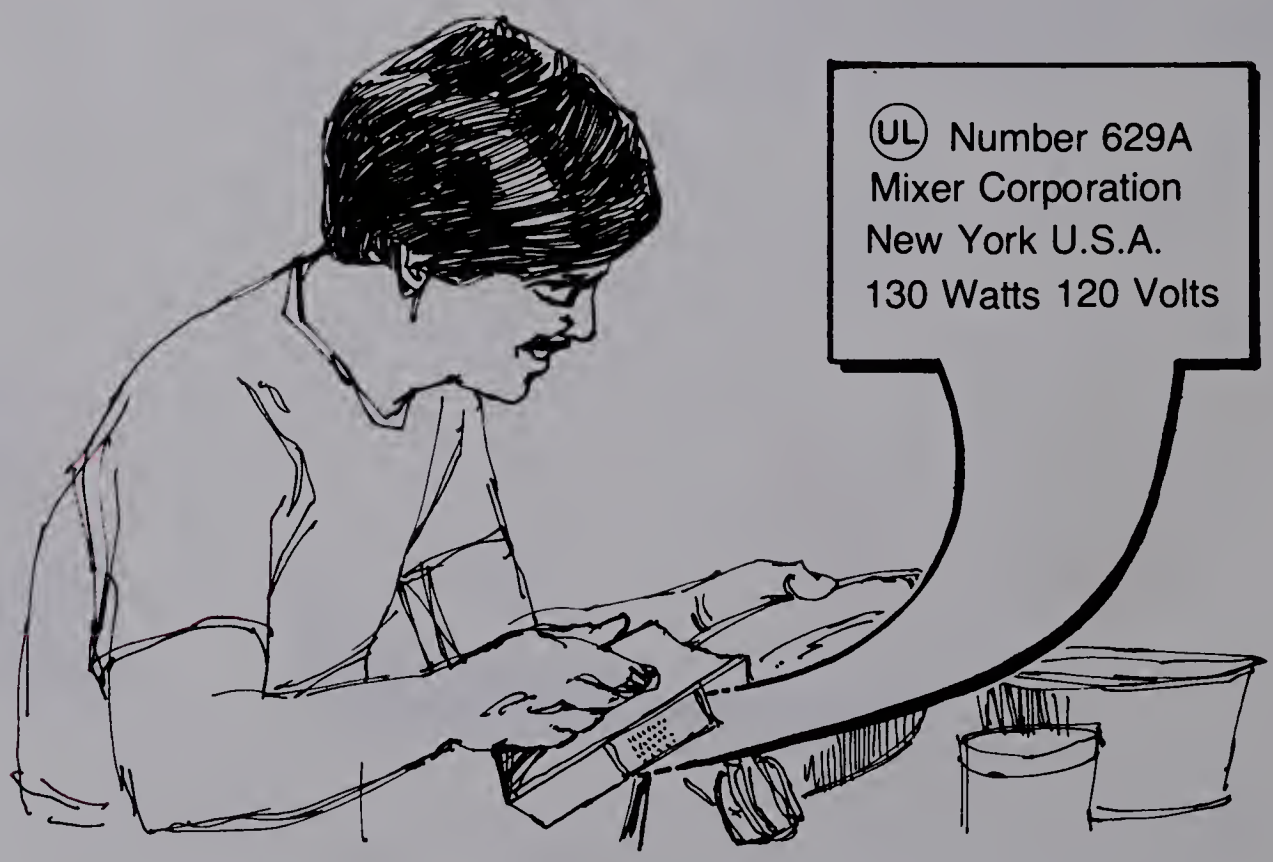
Activity 3

Gadgets that Work for You

MATERIALS PER STUDENT UNIT
dry cell, 1.5 V
DC voltmeter, 0–5 V
DC ammeter, 0–5 V
lamp bulb, 1.5 V
lamp socket
5 electrical leads



Energy is the capacity for doing work. Household gadgets that use energy can do work for you. Knowing how much energy an appliance uses can help you conserve energy. This may also mean you save money.



The "130 Watts, 120 Volts" on the label tells you how fast the appliance uses energy from a 120-volt outlet. Roberto uses the mixer for 10 seconds to beat eggs.

3–1. What is the wattage rating for Roberto's mixer?

3–1. 130 watts

You can find out how much energy the mixer used to beat the eggs by multiplying the wattage rating by the length of time it is used.

energy = watts X time

✔ 3–2. How much energy in watt seconds did Roberto's mixer use to beat the eggs?

3-2. 1300 watt seconds

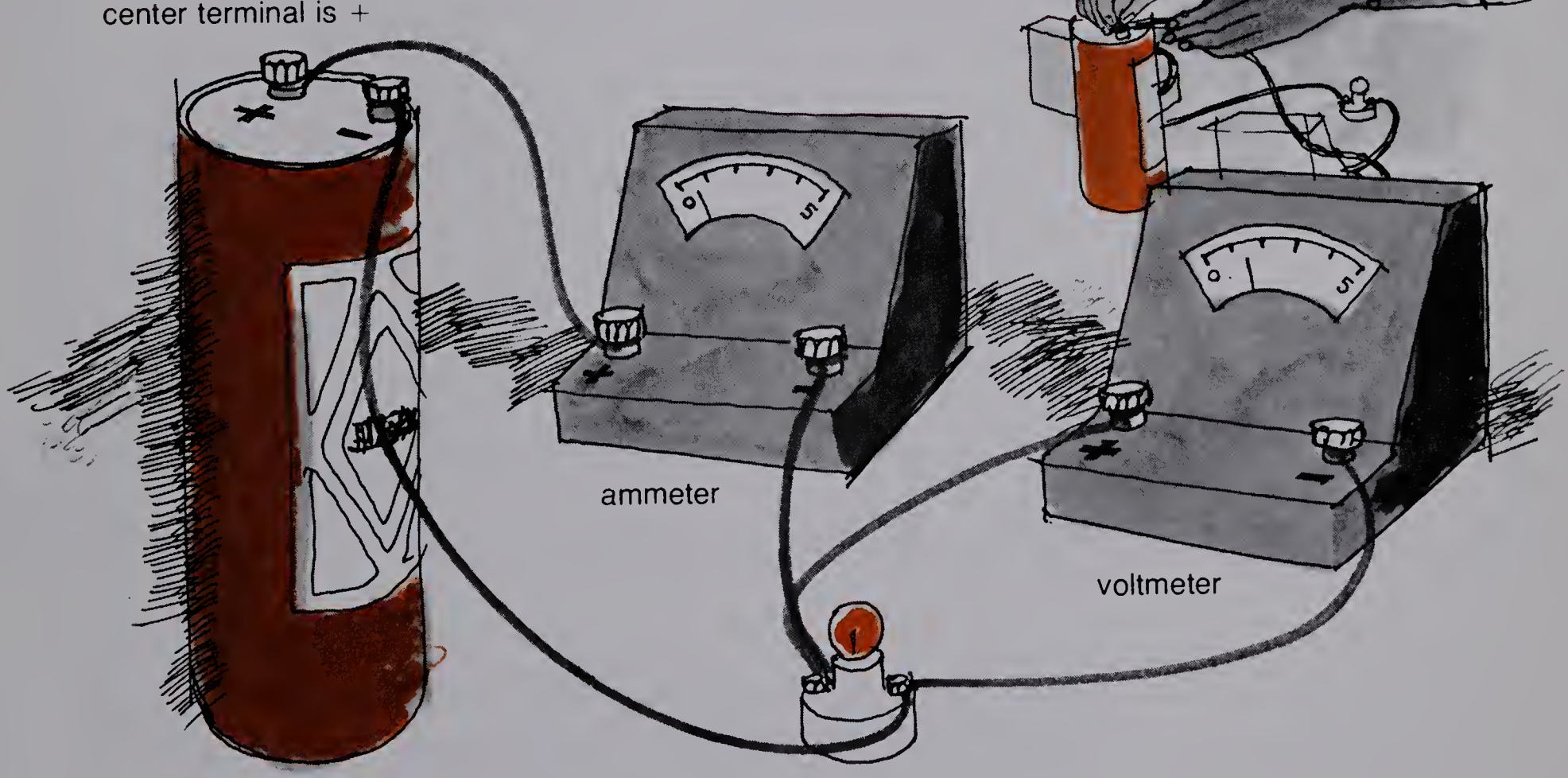
A more general term for the wattage rating of an appliance is *power.*

You can measure the power used by a small light bulb for yourself. You'll need just a few minutes and the following items:

dry cell, 1.5 V
DC voltmeter, 0–5 V
DC ammeter, 0–5 A
lamp bulb, 1.5 V
socket
5 electrical leads

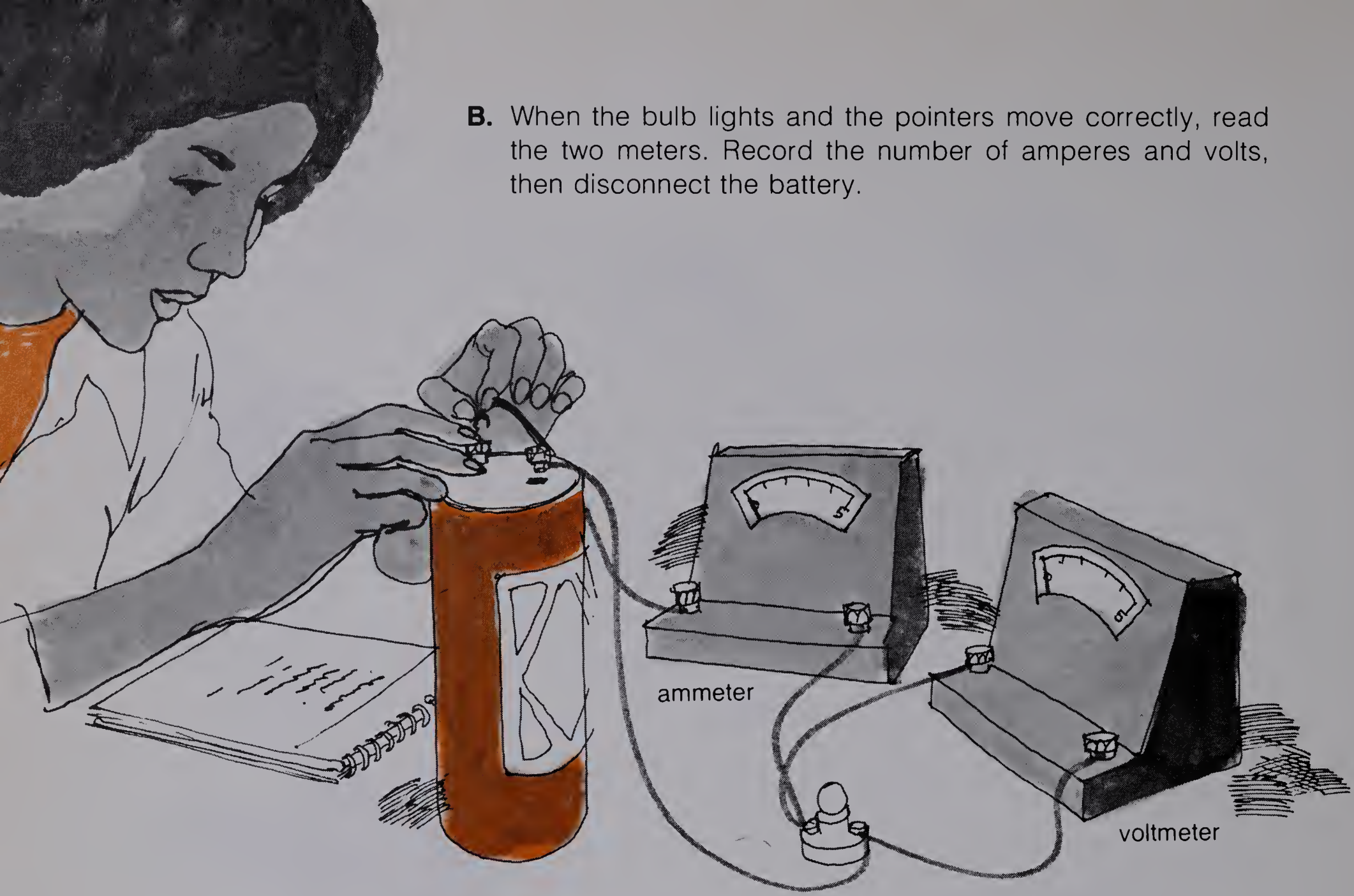
For a method to check dry cells see Advance Preparation p. TM 4.

A. Put the bulb in the socket. Connect the equipment as shown. Be sure the connections are tight.



✔ 3–3. Does the lamp light and do the pointers on the meters move in the correct direction? If not, check your circuit again. 3-3 Yes, the pointers move to the right.

B. When the bulb lights and the pointers move correctly, read the two meters. Record the number of amperes and volts, then disconnect the battery.



Now you can find out how much power the light bulb uses. To do this, you multiply the number of volts by the number of amperes.

watts = volts × amperes

3-4. 1.5 volts

3–4. What is the voltmeter reading in volts?

3-5. About 0.5 amperes (varies).

3–5. What is the ammeter reading in amperes?

3-6. About 0.75 watts (varies).

3–6. What amount of power in watts is the bulb using?

Your answer to Question 3–6 depends on the size of bulb you used. But the power is probably less than one watt. The little bulb doesn't use energy very rapidly. The electrical appliances in your home use energy a lot faster. For instance, the wattage rating for an electric clock is about 2, for a radio about 70, for a toaster about 1200, and for an electric stove about 12,000.

3-7. 1210 watts

3–7. How much power does a 110-volt toaster use if it needs 11 amperes of current?

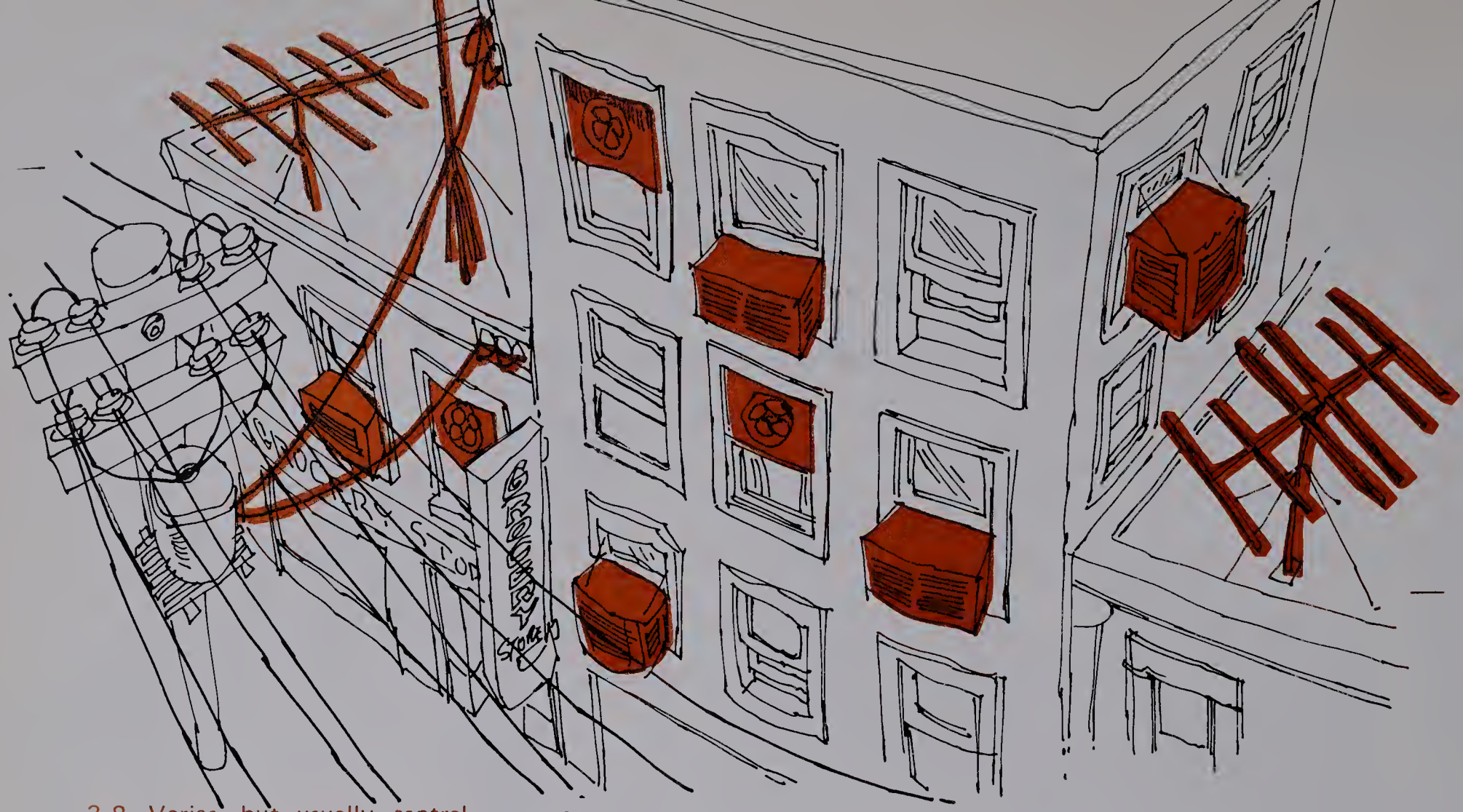
WATTAGE OF SOME COMMON ELECTRICAL APPLIANCES

APPLIANCE	AVERAGE WATTAGE	APPLIANCE	AVERAGE WATTAGE
Air conditioner (window)	1500	Heating unit (radiant)	12,000
Broiler	1500	Iron	1000
Carving knife	100	Radio	70
Clock	2	Radio-phonograph	100
Clothes dryer	5000	Range	12,000
Coffee maker	900	Refrigerator-freezer (14 cu ft)	300
Deep-fat fryer	1500	Refrigerator-freezer (frostless, 14 cu ft)	600
Dishwasher	1200	Sewing machine	75
Fan (roll-about)	200	Shaver	15
Floor polisher	300	Television (B & W)	250
Food blender	400	Television (color)	350
Food freezer (15 cu ft)	350	Toaster	1200
Food freezer (frostless, 15 cu ft)	450	Toothbrush	7
Food waste disposer	500	Vacuum cleaner	650
Frying pan	1200	Washing machine (automatic)	500
Hair dryer	400	Washing machine (nonautomatic)	250
Heat lamp (infrared)	250	Water heater (standard)	2500
Heater (portable)	1300	Water heater (quick recovery)	4500

Figure 3–1

The table in Figure 3–1 shows the average wattage ratings for some common appliances. Different brands and models vary from the figures shown in the table.

Not every home will have all the appliances listed in Figure 3–1. For instance, some homes don't have window air conditioners or a food waste disposer. Electricity is not used for heating and cooking in all homes.

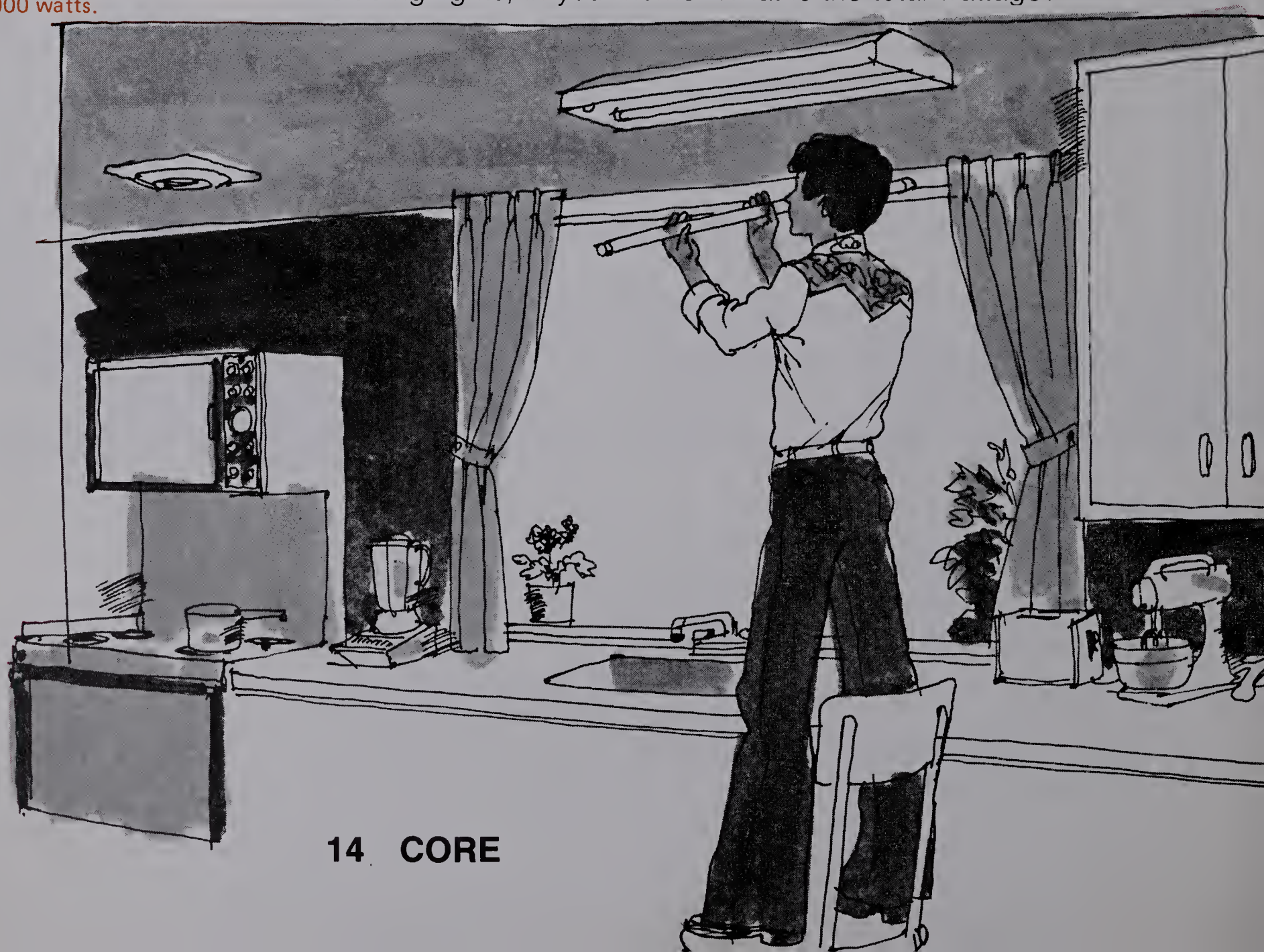


3-8. Varies, but usually central heating, range, clothes dryer. Varies, but usually clock, toothbrush, shaver.

3-9. Varies, but may be upward of 50,000 watts.

✔ 3–8. Which electrical appliance in your home has the highest wattage rating? The lowest wattage rating?

✔ 3–9. Estimate the wattage of all electrical appliances, including lights, in your home What is the total wattage?



What can be done to save energy? Plenty, if you know how to go about it. Using the data from Figure 3–1, let's look at some examples.

✔ 3–10. Rearrange the following appliances into two seven-item lists in your notebook. Head one list "With Heating Element" and the other "Without Heating Element." Place the wattage of each appliance beside its name.

Broiler
Central heating unit
Clock
Clothes dryer
Deep-fat fryer
Dishwasher
Fan
Floor polisher
Food blender
Frying pan
Iron
Sewing machine
Shaver
Vacuum cleaner



3-10. *With heating element*

Broiler	1500
Central heating unit	12,000
Clothes dryer	5000
Deep-fat fryer	1500
Dishwasher	1200
Frying pan	1200
Iron	1000

Without heating element

Clock	2
Fan	200
Floor polisher	300
Food blender	400
Sewing machine	75
Shaver	15
Vacuum cleaner	650

★ **3–11. On the basis of your lists, which costs more to run, appliances with heating elements or with motors only?**

3-11. Those with heating elements.

When electrical energy is changed to heat, it is used at a greater rate. It isn't going to save much energy to turn off the electric clock (and it may make you late). But cutting down on things that have heating elements will really help.

Of course, you don't turn on all the appliances at once. But the answer to Question 3–9 probably surprised you. All together, appliances represent a high rate of using energy—a large amount of power.

More and bigger gadgets are gobbling up larger amounts of power all the time. And where there are fuel shortages, energy is costing more. Anything you do to reduce power consumption will help.



✔ 3–12. What would reducing by one-third the time a hot-water heater operates do to the amount of energy used?

3-12. Reduce it by 1/3.

✔ 3–13. The drying cycle in a dishwasher accounts for half the total energy. If one load requires 1200 watt hours of energy, about how many watt hours is used in drying?

3-13. 600 watt hours

✔ 3–14. A solid state color TV uses 20 percent less energy than a regular color TV. By how much would this change the wattage for a color TV in Figure 3–1?

3-14 by 70 watt hours to 280 watt hours.

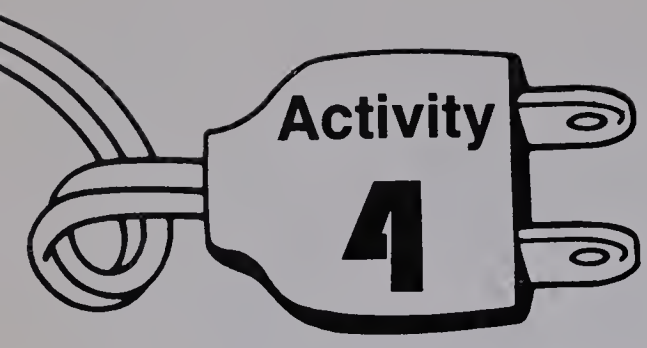
★ **3–15. An air conditioner has a thermostat. How might it be set in summer to save energy?**

3-15. To a higher temperature.



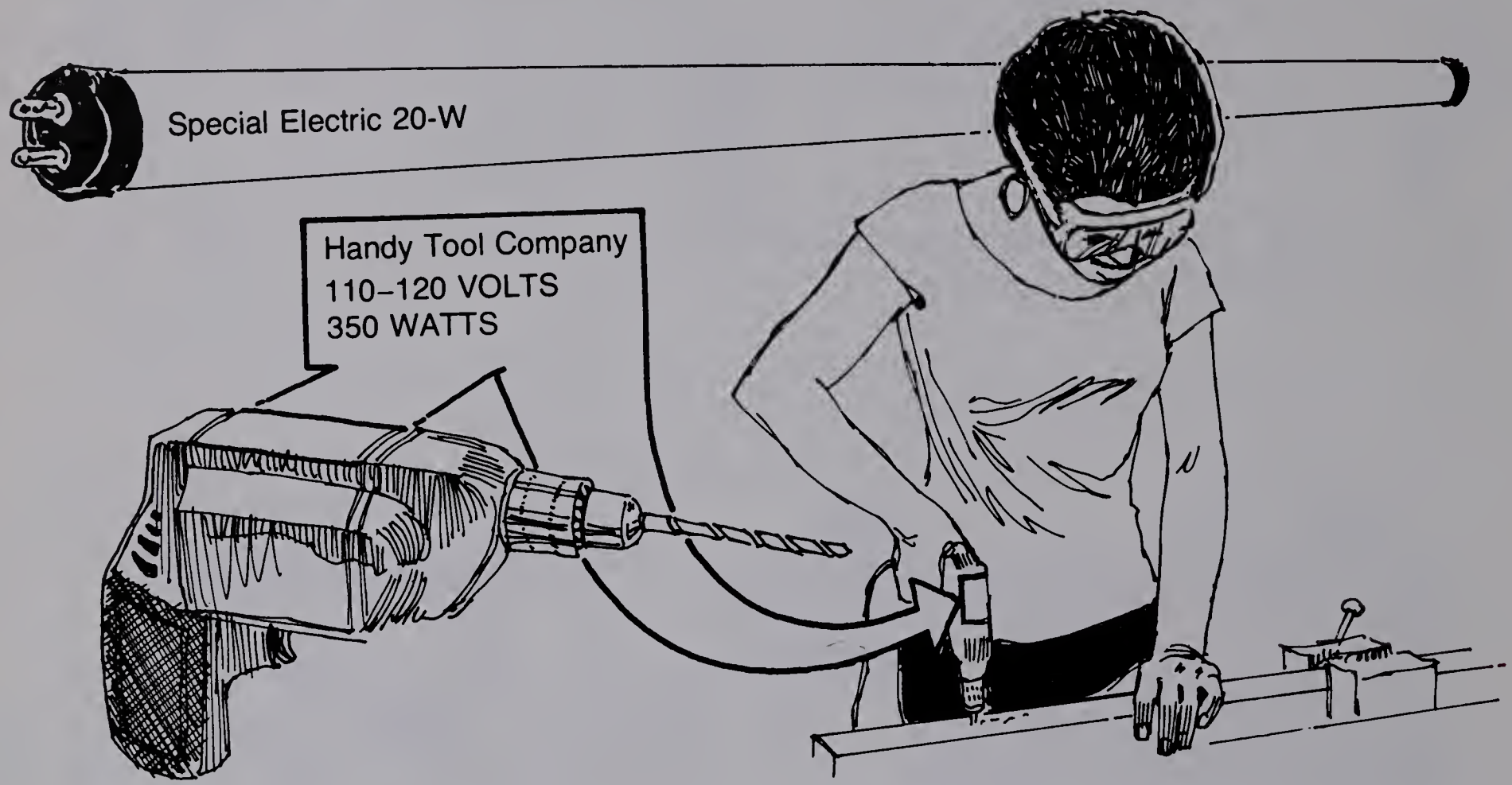
Normally a shower, especially under the conditions given here, uses much less hot water than a tub bath.

ACTIVITY EMPHASIS: The unit, kilowatt hour, by which electricity is sold can be calculated or read from electric meters.



House Power

The *watt* is a very common unit of power. Generally wattage is printed on light bulbs and appliances. It tells how fast the light bulb or appliance uses electrical energy.



MATERIALS PER STUDENT UNIT
None.

If you know how fast a car traveled and you multiply by how long it traveled, you can tell how far it went. In the same way, if you know how fast energy was used and you multiply by how long it was used, you find the total energy used.



4–1. 1000 watt seconds

✔ 4–1. How much energy is used by a 100-watt bulb burning for 10 seconds?

A 100-watt bulb isn't a very big energy user, and 10 seconds isn't a long time. So 1000 watt seconds isn't a lot of energy. You need a larger unit for measuring energy in the home.

ONE KILOWATT *is* 1000 WATTS

In an hour, a 1000-watt appliance uses a *kilowatt hour* of energy. That's abbreviated kW h. It's a lot bigger unit than the watt second —3,600,000 times as big! And it's the unit used in the electric meter in your home. Figure 4–1 shows three different electric meters.



Figure 4–1

Check your own meter at home. You may find it is different from those in Figure 4–1. To read the right-hand meter, you simply read the number showing on the face of the meter.

4–2. How many kilowatt hours have been used based on the meter on the right?

4-2. 264 kW h

Many meters are like the other two shown. They are not easy to read. Look at Figure 4–2.

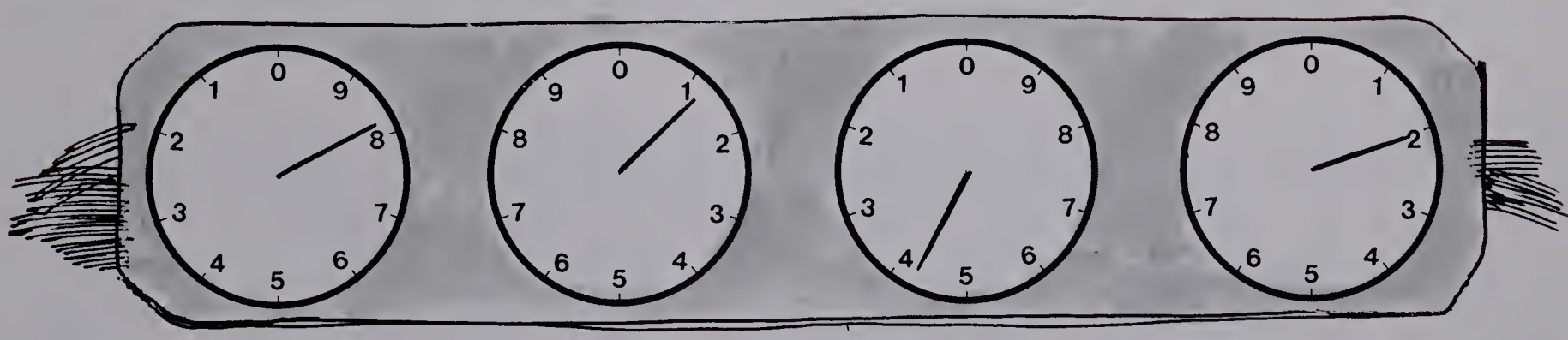


Figure 4–2

4–3. How many kilowatt hours are shown by the four dials in Figure 4–2?

4-3. 8142

To obtain a meter for display see Advance Preparation p. TM 5.

If you got 8142 kW h, consider skipping the rest of this activity.

Do you notice something strange about the dials in Figure 4–2? That's right, every other dial is read backwards! This is because of the way the dials are geared together. The gear wheel of one dial causes the gear wheel of the dial on its left to turn, and so on down the line.

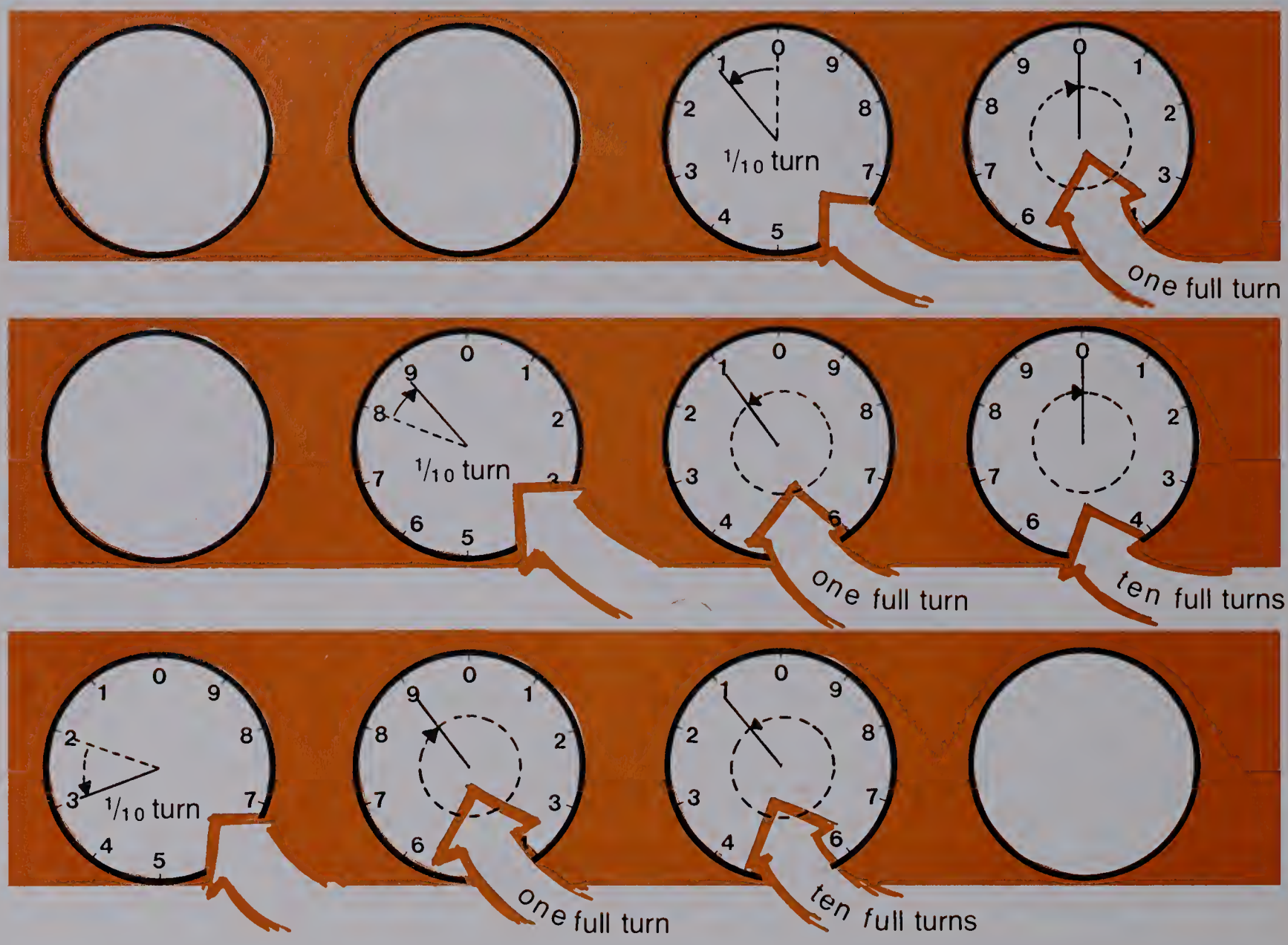


Figure 4–3

What this means is that each dial counts ten times more than the dial to the right. The value of the numerals on the four dials is shown in Figure 4–4.

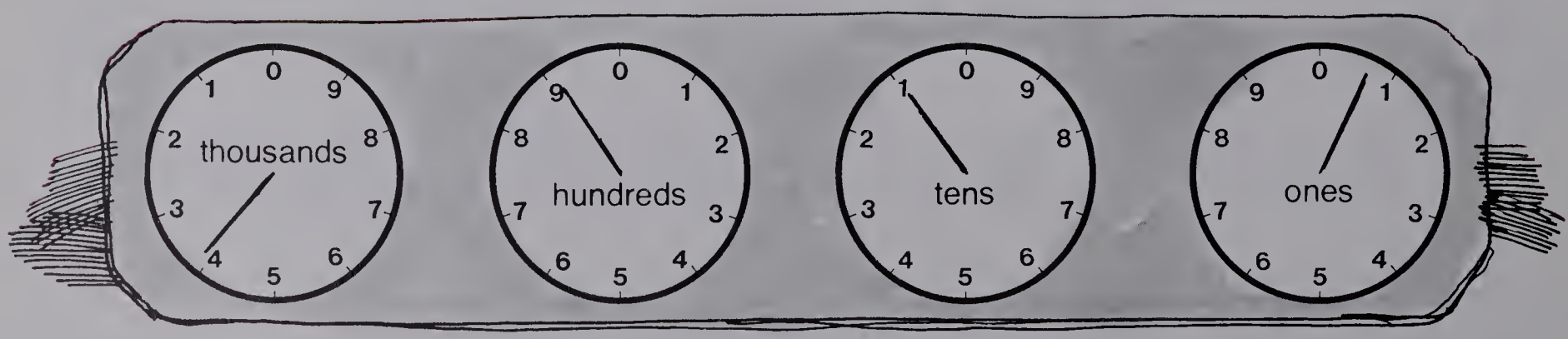


Figure 4–4

4–4. How would you read a dial if the pointer was between the three and the four? 4-4. 3

When the pointer is between two numbers on the dial, the reading taken is the lower of the two numbers.

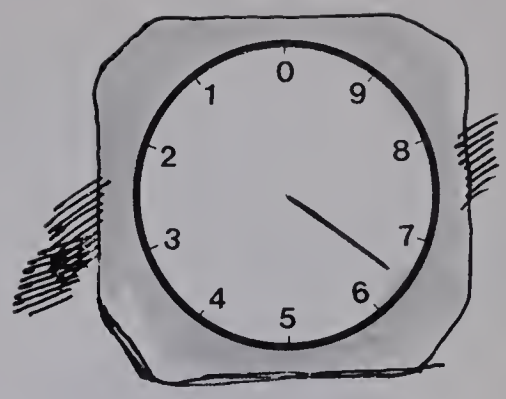


Figure 4–5

4–5. How would you read the dial in Figure 4–5? 4-5. 6

4–6. What is the meter reading for Figure 4–4? 4-6. 3910

Of course, you read the meter dials just as any 4-digit number. Reading from left to right, you get 3 thousands, 9 hundreds, 1 ten and no ones, or 3910 kW h.

Now try another one.

4–7. What reading is shown by the dials in Figure 4–6? 4-7. 4732

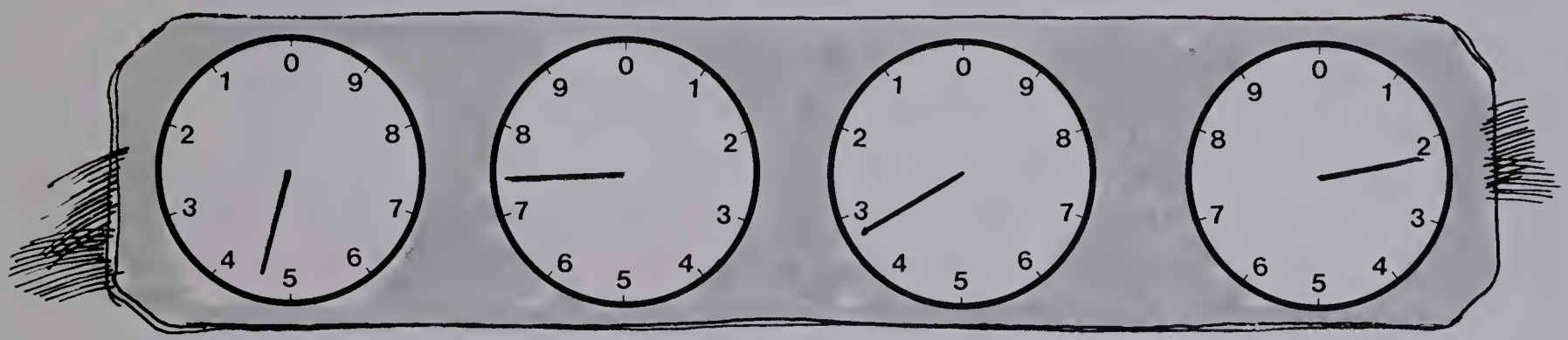


Figure 4–6

After you have answered Question 4–7, turn to the end of this activity to find the correct answer. If you missed, you should go back over the procedure.

If the meter has five dials, as the one shown in the middle of Figure 4–1, then you just read a five-digit number instead of a four-digit number. The same rules apply. Try one.

4–8. What reading is shown by the dials in Figure 4–7? 4-8. 35874



Figure 4–7

Now that you know how to read a meter you can find out how much electrical energy your family uses in a month. Suppose the electric meter for your home looked like the one in Figure 4–8.

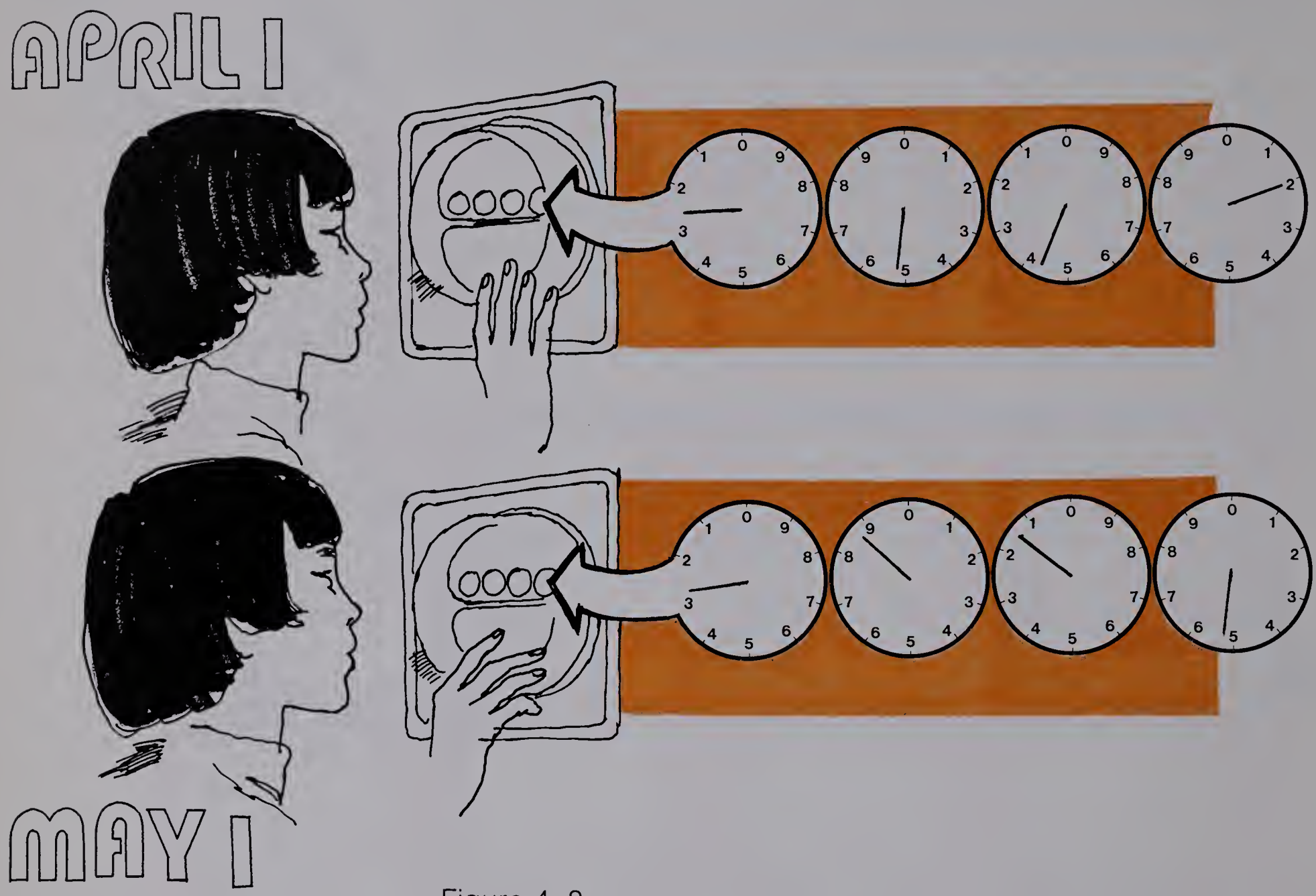


Figure 4–8

4-9. 2542

✔ 4–9. What is the meter reading for April 1?

4-10. 2815

✔ 4–10. What is the meter reading for May 1?

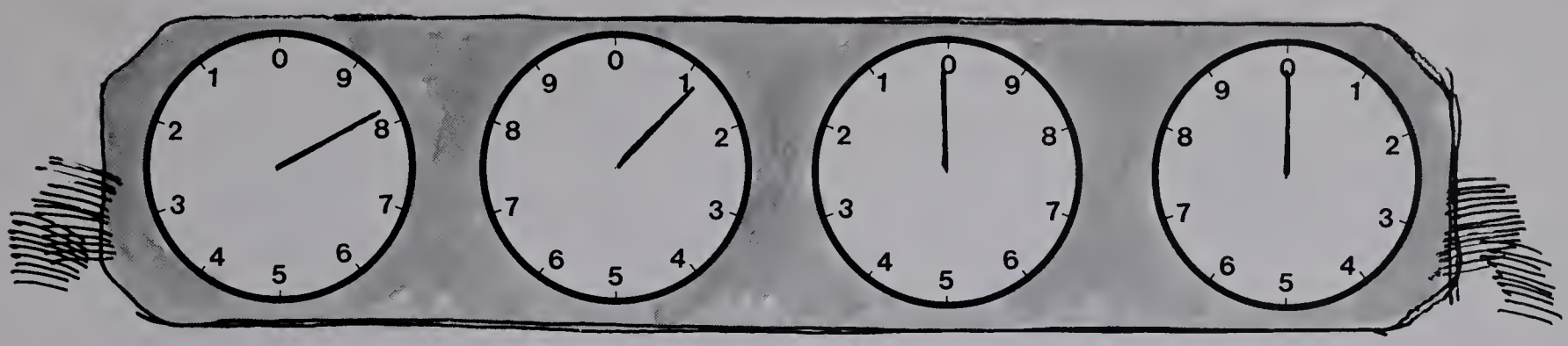
On April 1 the meter read 2542, on May 1 the reading was 2815. To find out how many kilowatt hours were used during April, subtract the April reading from the May reading.

2815 reading for May 1
− 2542 reading for April 1
273 kW h used during April

4-11. 456 kW h (8556-8100)

★ **4–11. Using the two electric meter readings in Figure 4–9, how much electrical energy (in kW h) was used between the times the meter was read?**

first reading



second reading

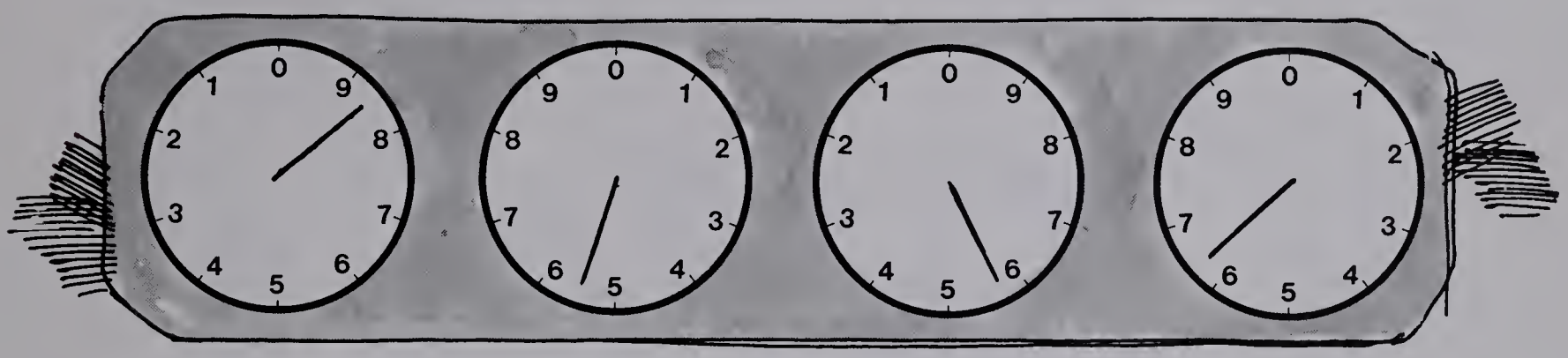


Figure 4–9

Answers

4–7. 4732 kW h 4–8. 35,874 kW h

ACTIVITY EMPHASIS: Sliding rate charge and fuel adjustment charge determine an electricity bill.

It's Energy You Pay For



Activity 5

MATERIALS PER STUDENT UNIT

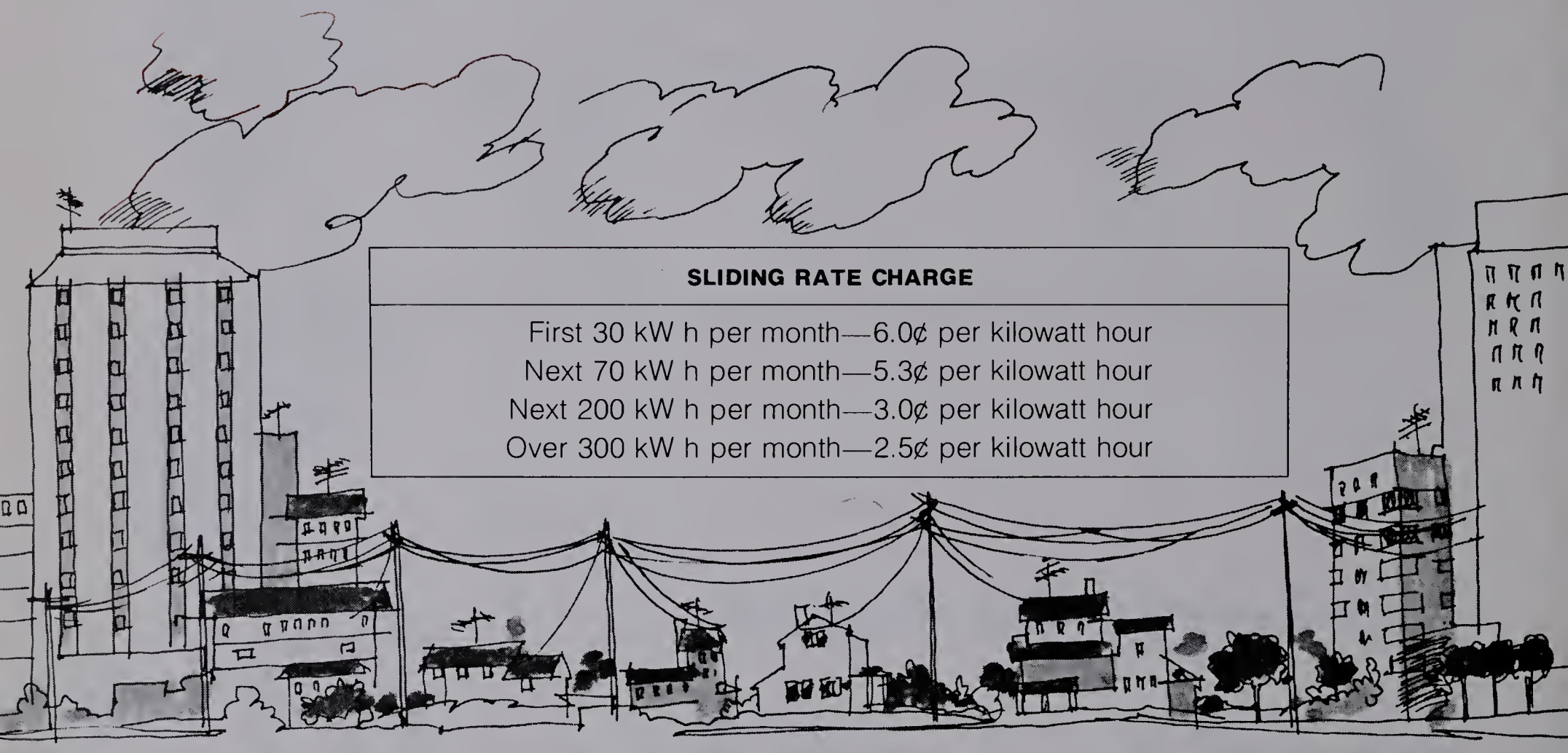
None.

See Advance Preparation p. TM 5.

Fuel oil, bottled gas, and gasoline are sold by the gallon. Natural gas is sold by the cubic foot. It's easy to figure the cost of energy from these sources, since it's usually so much a gallon or cubic foot. But electricity is priced differently.

Sliding rate could form basis for a discussion: Should heavy users of electricity get an advantage?

Most electric companies charge a "sliding rate" for electrical energy. The cost per unit goes down as you use electricity. Figure 5–1 shows the sliding rate for electricity charged in a city in Florida.



SLIDING RATE CHARGE
First 30 kW h per month—6.0¢ per kilowatt hour
Next 70 kW h per month—5.3¢ per kilowatt hour
Next 200 kW h per month—3.0¢ per kilowatt hour
Over 300 kW h per month—2.5¢ per kilowatt hour

Figure 5–1

Suppose your meter shows that you used 864 kW h during the past month. This is how your bill would be figured:

First 30 kW h	$30 \times 6.0 = \$1.80$
Next 70 kW h	$70 \times 5.3 = \$3.71$
Next 200 kW h	$200 \times 3.0 = \$6.00$
Remaining 564 kW h	$564 \times 2.5 = \$14.10$
Total for 864 kW h	$= \$25.61$

5-1. $22.26

✔ 5–1. Using the rates shown in Figure 5–1, find the bill for a family that used 730 kW h in a month.

Much of the electric power in the United States is generated by using fuel oil or natural gas. But in recent years we've run into trouble. Some of the troubles are shown in Figure 5–2.

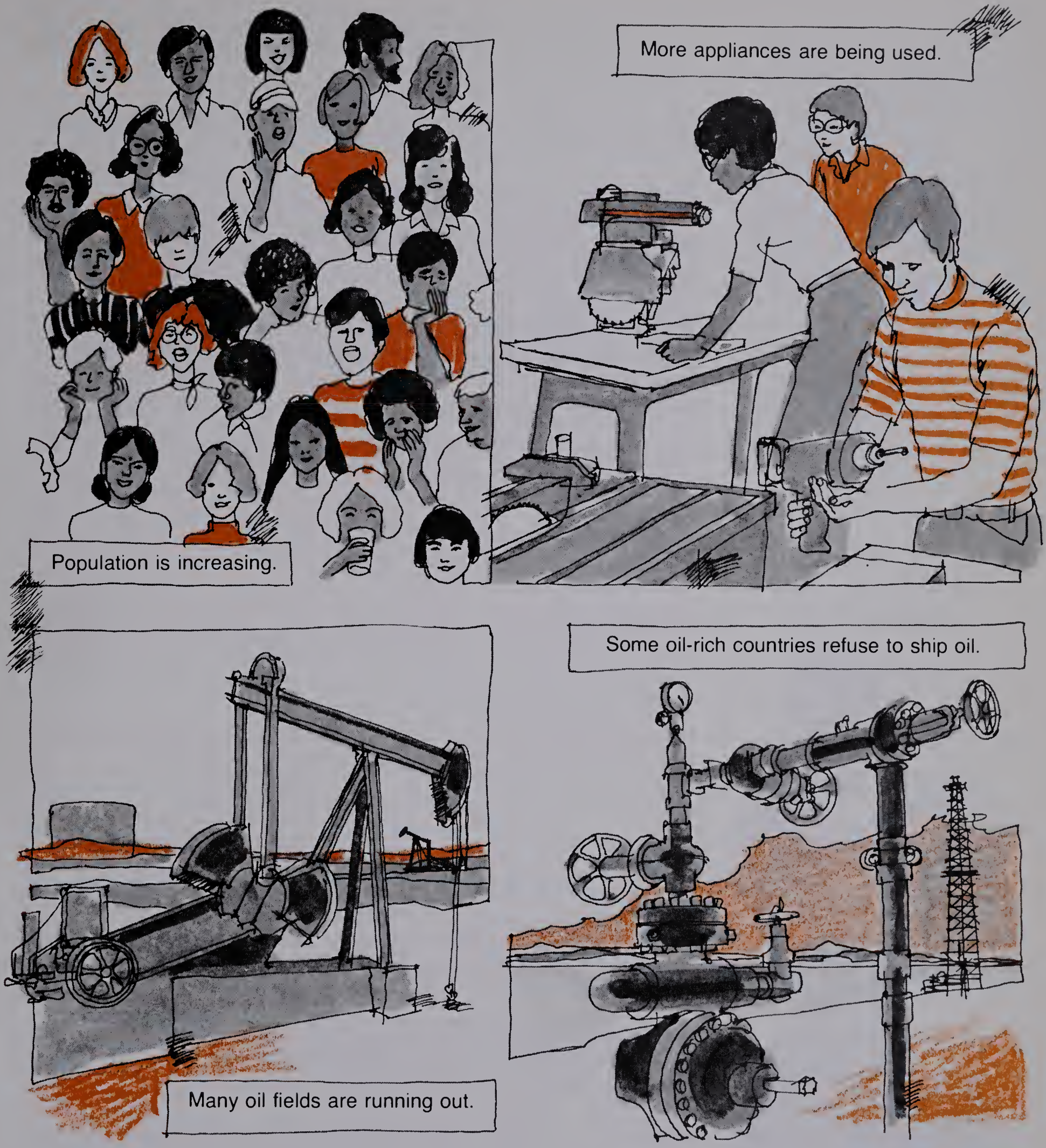


Figure 5–2

✔ 5–2. What effect do the four factors in Figure 5–2 have on the amount of fuel oil available and needed for power production?

5-2. The amount available is reduced.



When supply is low and demand is high, prices tend to go up. Inflation drives prices even higher. Fuel oil prices have increased several times in the last few years.

5–3. How do fuel oil prices affect the cost of electric power?

5-3 May lower or raise the cost.

Many power companies have added a "fuel adjustment" charge to the monthly bill to take care of the increase in fuel prices. It's figured as a percentage of the electrical energy used, or as a certain amount added for each kilowatt hour.

★ **5–4. What reason is given for adding a fuel adjustment charge to the electric bill in some localities?**

5-4. Increased cost of fuel for generating electricity.

In the first example shown in this activity, 864 kW h cost $25.61. If the fuel adjustment charge is 25%, this is how the fuel adjustment charge would be figured.

$$\$25.61 \times 25\% = \$6.40$$
$$\$25.61 + \$6.40 = \$32.01$$

The cost of the electrical energy ($25.61) added to a percentage of this amount ($6.40) gives the total bill ($32.01).

Instead of a percentage, suppose the fuel adjustment charge is one cent per kilowatt hour ($0.01/kW h).

$$864 \text{ kW h} \times \$.01 = \$8.64$$
$$\$25.61 + \$8.64 = \$34.25$$

The cost of the electrical energy by the sliding scale ($25.61) added to the additional charge ($8.64) figured on one cent per kW h (864) gives the total bill ($34.25).

Now put it all together. Start with the monthly meter reading in Question 5–5.

★ **5–5. The March 1 reading on a meter was 5267 kW h; on April 1 it was 5907 kW h. Using the rates shown in Figure 5–1, find the cost of the energy used.** 5-5. $20.01

5–6. If the fuel adjustment charge is 25%, how much is added to the bill? 5-6. $5.00

5–7. What is the total bill? 5-7. $25.01

Energy costs. As fuel gets scarcer, it will cost more and more.

ACTIVITY EMPHASIS: Fuel oil, natural gas, electricity, coal and wood vary in convenience and cost effectiveness as home heating fuels.

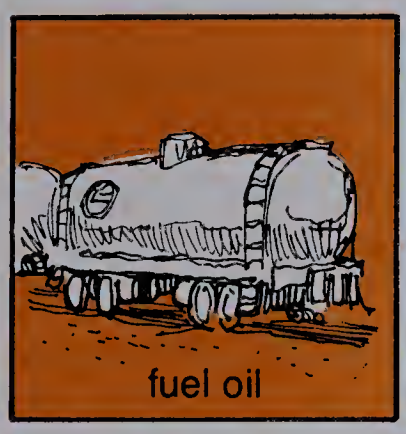
Your Money's Worth

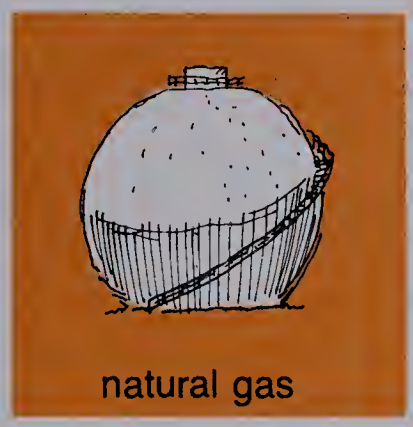


MATERIALS PER STUDENT UNIT

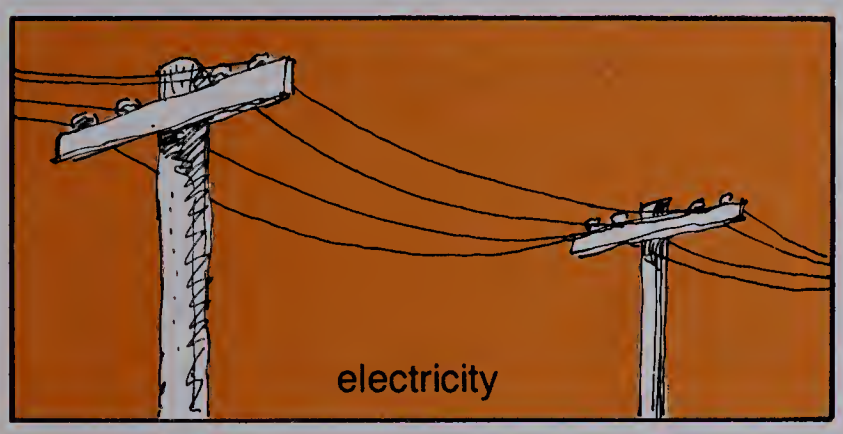
None.

How is your home heated? How you answered depends on how you looked at the question. You might have thought of energy sources such as these—


fuel oil


natural gas

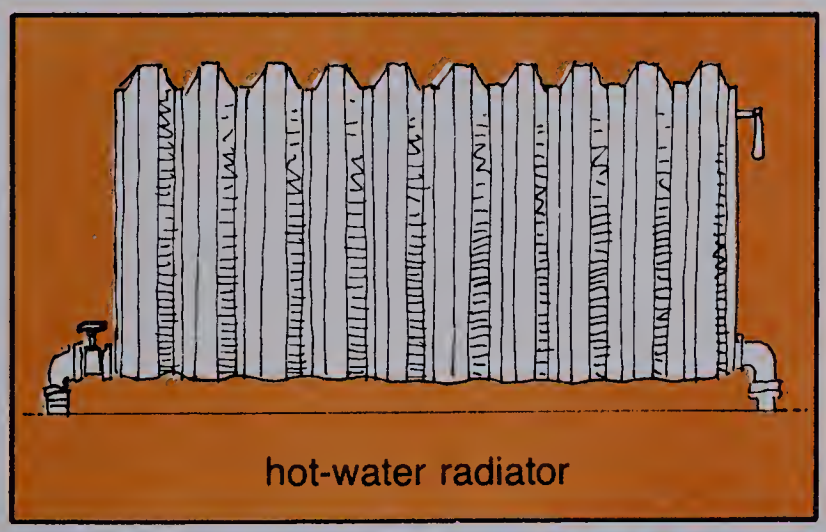

wood

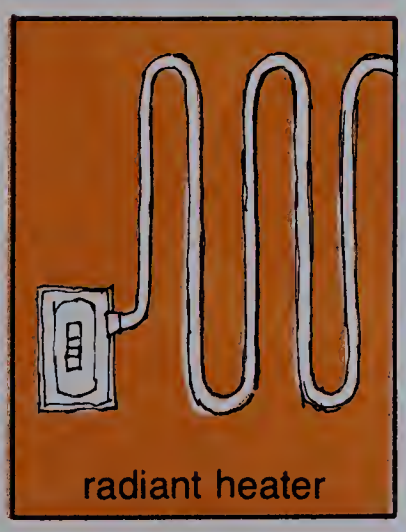

electricity

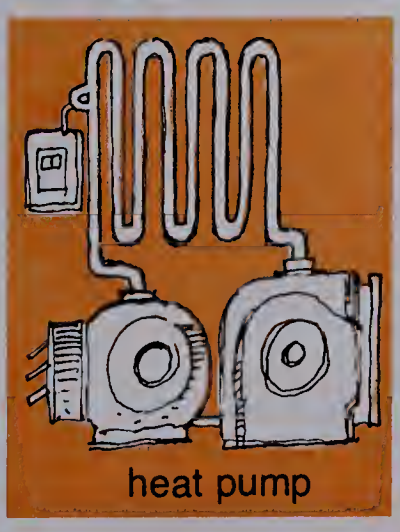

coal

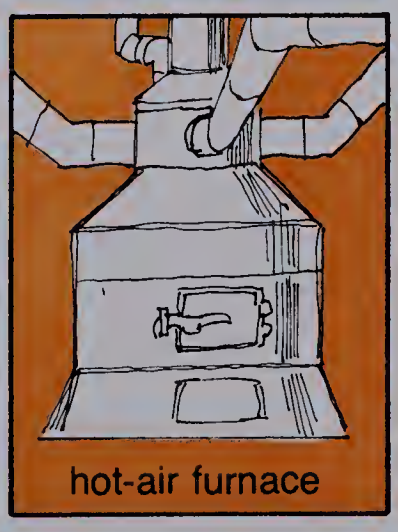
Or you might have thought of heating devices such as these—


stove


hot-water radiator


radiant heater


heat pump


hot-air furnace



You might have been really "scientific" and named convection, conduction, or radiation. These are ways heat is transferred.

Of course, if you live far enough south, you might have said "no way." You get all the heat you need from the sun.

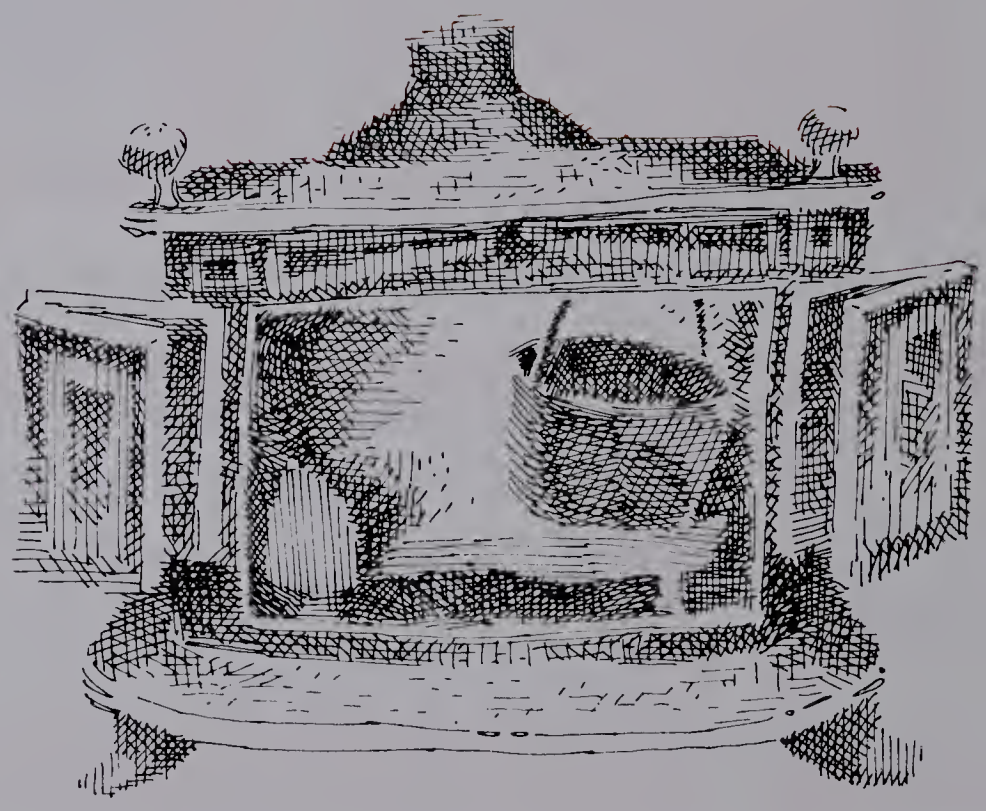
In this activity, methods of home heating will refer to the energy source. The five principal sources are fuel oil, natural gas, electricity, coal, and wood.

✔ 6–1. Which energy source is used to heat your home?

6-1. Answers will vary.

Of the five principal sources, four depend on burning the fuel in a firebox connected to a chimney. The poisonous gases from the burning fuel are kept separate from air that is used to heat the building. On the other hand, keeping them separate means that heat cannot be transferred as well.

✔ 6–2. What is there about gases from burning fuel that requires them to be kept separate from the air that heats a building? 6-2. They are both poisonous and irritating.



6-3 Wood and coal make ashes.

✔ 6–3. What's different about the products from burning wood and coal as compared to those from burning fuel oil and natural gas?

Once, just about all home heating was done with wood or coal. But these two fuels aren't as convenient to use as fuel oil and natural gas. They leave ashes that must be removed, and they don't flow into the firebox.

6-4. Wood and coal.

★ **6–4. Of the five principal energy sources for home heating, which two are not used as much as they used to be?**

When homes are heated by electricity, heating coils may be used. The coils can be in separate radiant heaters, as in Figure 6–1, or in units built into the floors or walls.

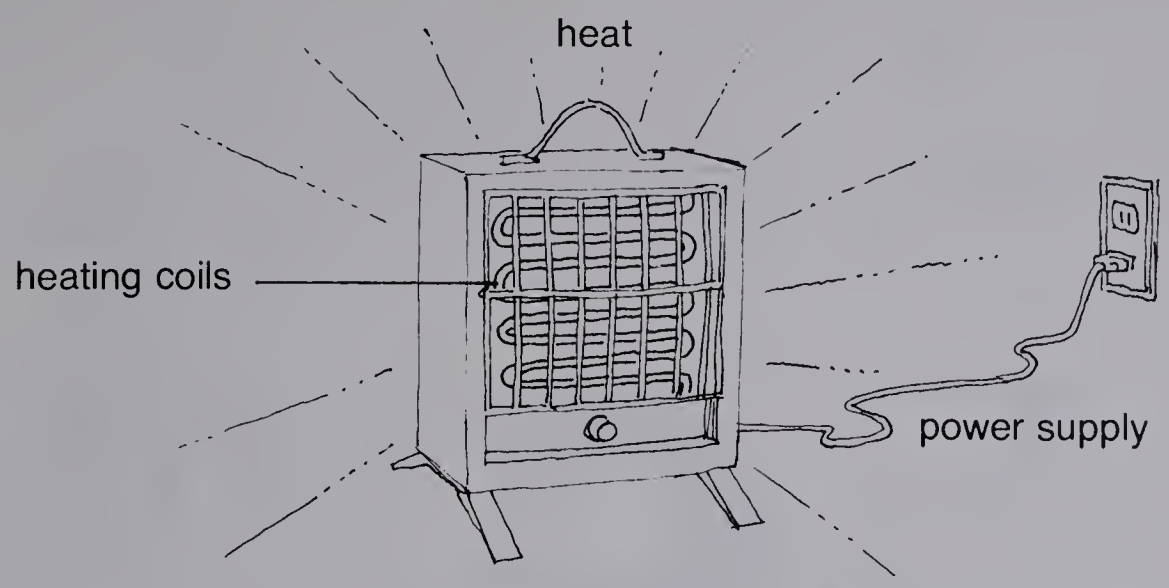


Figure 6–1

✔ 6–5. What advantage do you think electricity has over burning fuels?

6-5 No fumes, smoke, or burning gases and heat can be transferred better.

Another way homes may be heated by electricity is a little more complicated. It involves a device called a *heat pump* (Figure 6–2).

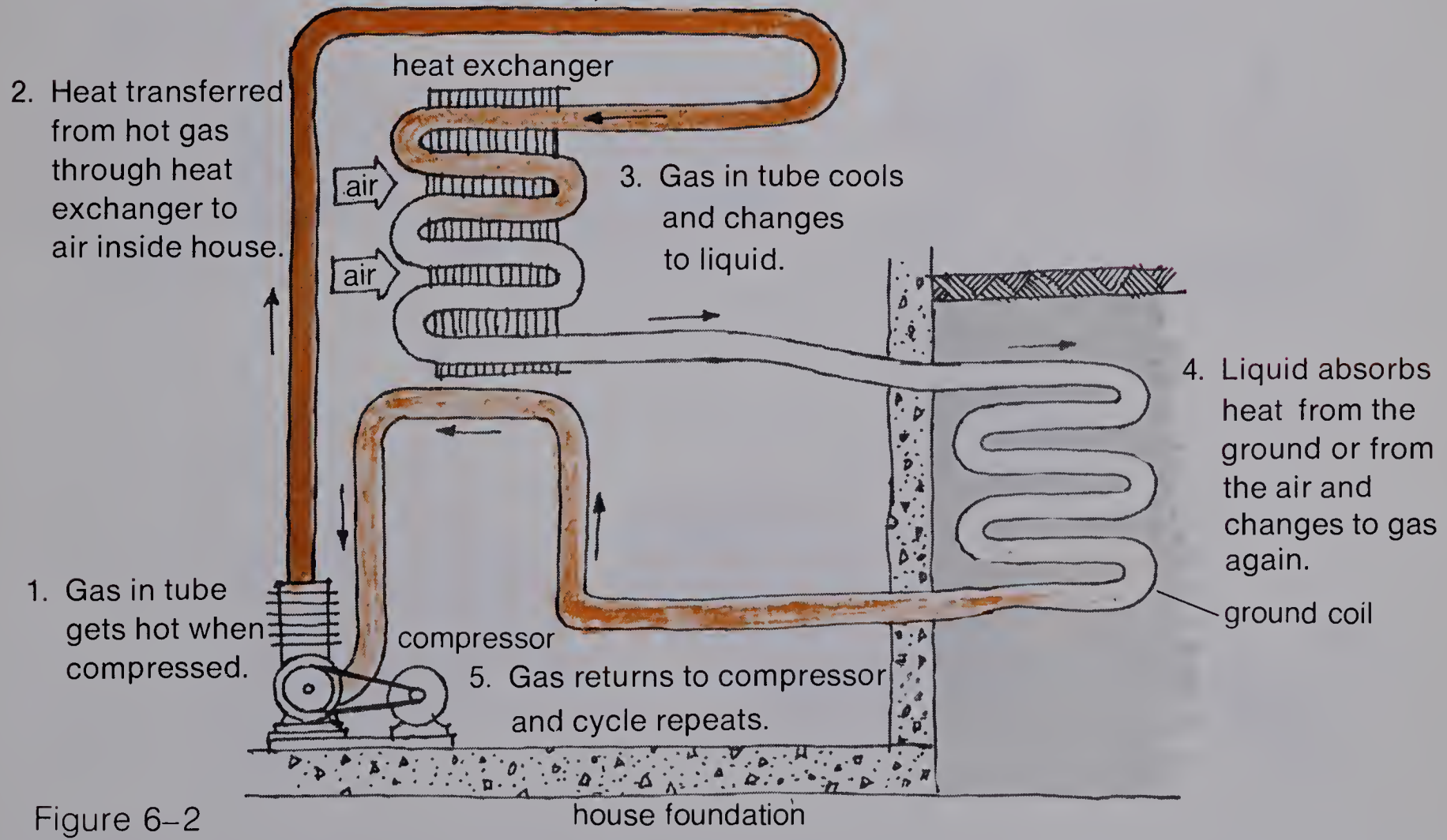


Figure 6–2

✔ 6–6. How is heat transferred from the heat pump to the house?

6-6. By air that was blown over hot coils.

See Advance Preparation p. TM 5.

Energy Cost

What about the cost of fuels that are used for heating? Which energy source do you think provides the most energy for each dollar spent? When you're paying for energy, you want to get your money's worth.

Comparing the energy from different sources is something like adding apples and oranges. You need a common unit to make comparisons.

Btu ¢ kWh

Suppose kilowatt hours is chosen as the common unit. Then the cost of a kilowatt hour of energy from each source can be compared. But, there's another thing to consider. Not all the energy removed from a source is useful energy. Look at Figure 6–3.

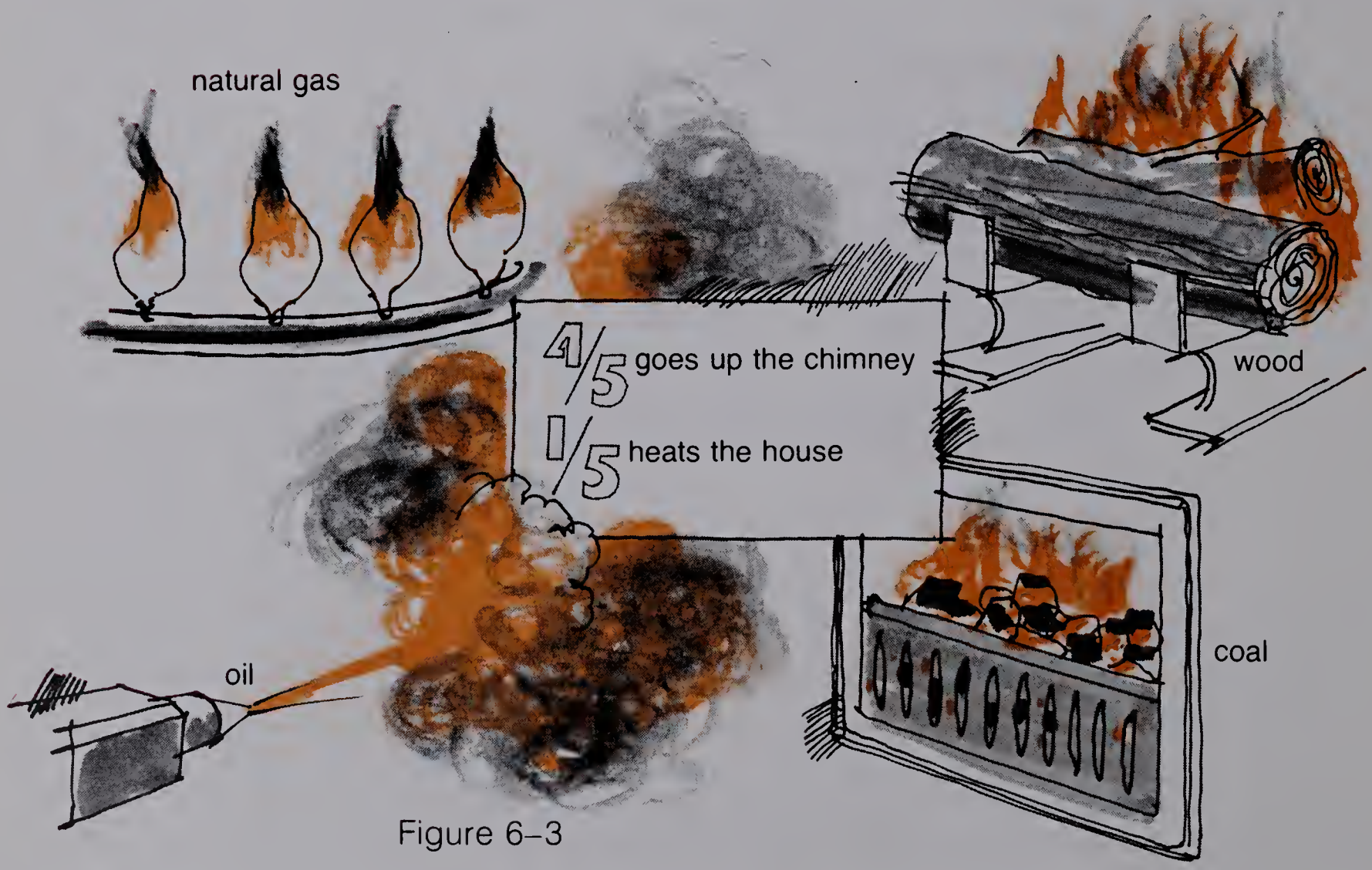


Figure 6–3

With the electrical energy, however, the figures are the other way around. About $\frac{4}{5}$ of the energy used in an electric heater is useful energy. Only about $\frac{1}{5}$ is wasted.

Figure 6–4 compares the cost of heat energy from various sources. The energy units for all the sources have been changed to kilowatt hours. The right-hand column gives useful kilowatt hours per dollar.

COST OF HEAT ENERGY FOR HOMES

ENERGY SOURCE	COST	TOTAL KW H PER DOLLAR	USEFUL KW H PER DOLLAR
Fuel oil	35¢ per gallon	114	23
Natural gas	0.3¢ per cubic foot	93	19
Household electricity	4¢ per kW h	25	20
Coal	$46 per ton	180	36
Wood	$46 per cord	138	28

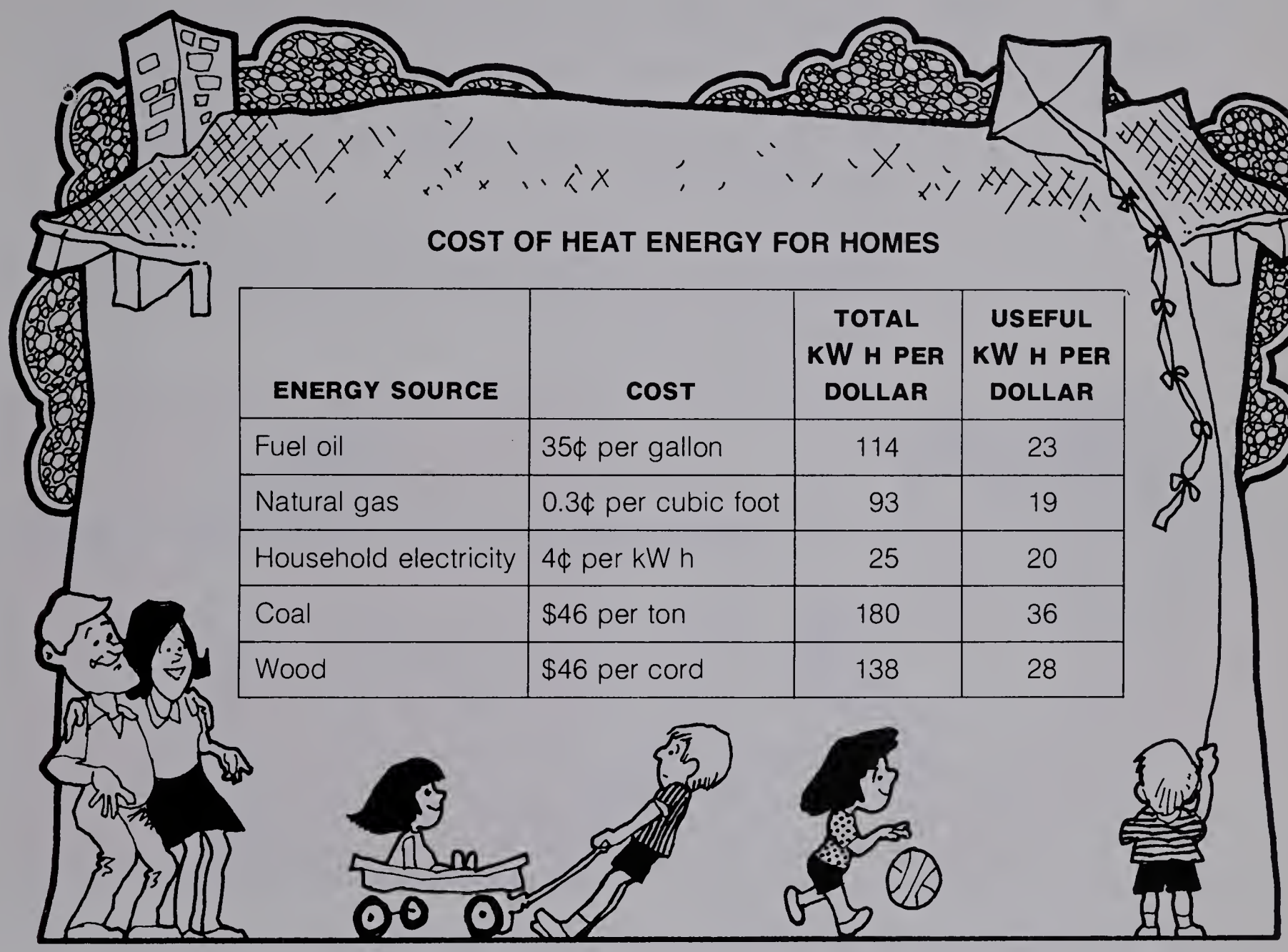


Figure 6–4

✔ 6–7. Why is it necessary to list all the energy sources in kilowatt hours per dollar?

6-7. For a common basis for comparison.

✔ 6–8. Why is there such a big difference between the total energy per dollar and the useful energy per dollar for the fuels?

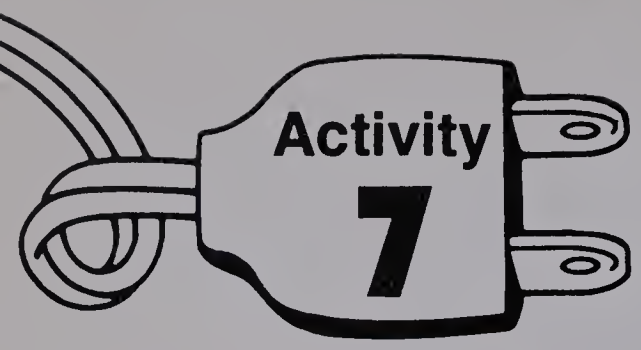
6-8. For some fuels, much of the heat goes up the chimney.

✔ 6–9. Of the five energy sources listed, which one gives you the most useful energy for your dollar? Which gives you the least?

6-9. Most: coal. Least: natural gas.

Of course, these prices are changing all the time, and they're different in different localities. You may have prices much higher than those shown in the table. But you can still compare to see if you're getting your money's worth.

ACTIVITY EMPHASIS: Furnaces and air conditioners maintain a constant temperature in a room through feedback control. Students heat a bimetal strip.



MATERIALS PER STUDENT UNIT

bimetal strip
rubber band
metre stick
match
Resource Unit 13

Constant Temperature

Your body temperature holds pretty constant at about 37°C (98.6°F). Night or day, summer or winter, it doesn't change very much—unless you're sick or something is wrong in your body.

7–1. What generally happens to your body temperature when you are ill? 7-1. It goes up.

Because people's bodies are at a constant temperature, most people feel more comfortable if their surroundings are kept at a constant temperature also.



If your body loses heat easily to the surroundings, it's too cold. You shiver and shake.



If your body has a hard time losing heat to the surroundings, it's too hot. You perspire.



7–2. At about what temperature do you feel most comfortable in your home? 7-2. Answers will vary.

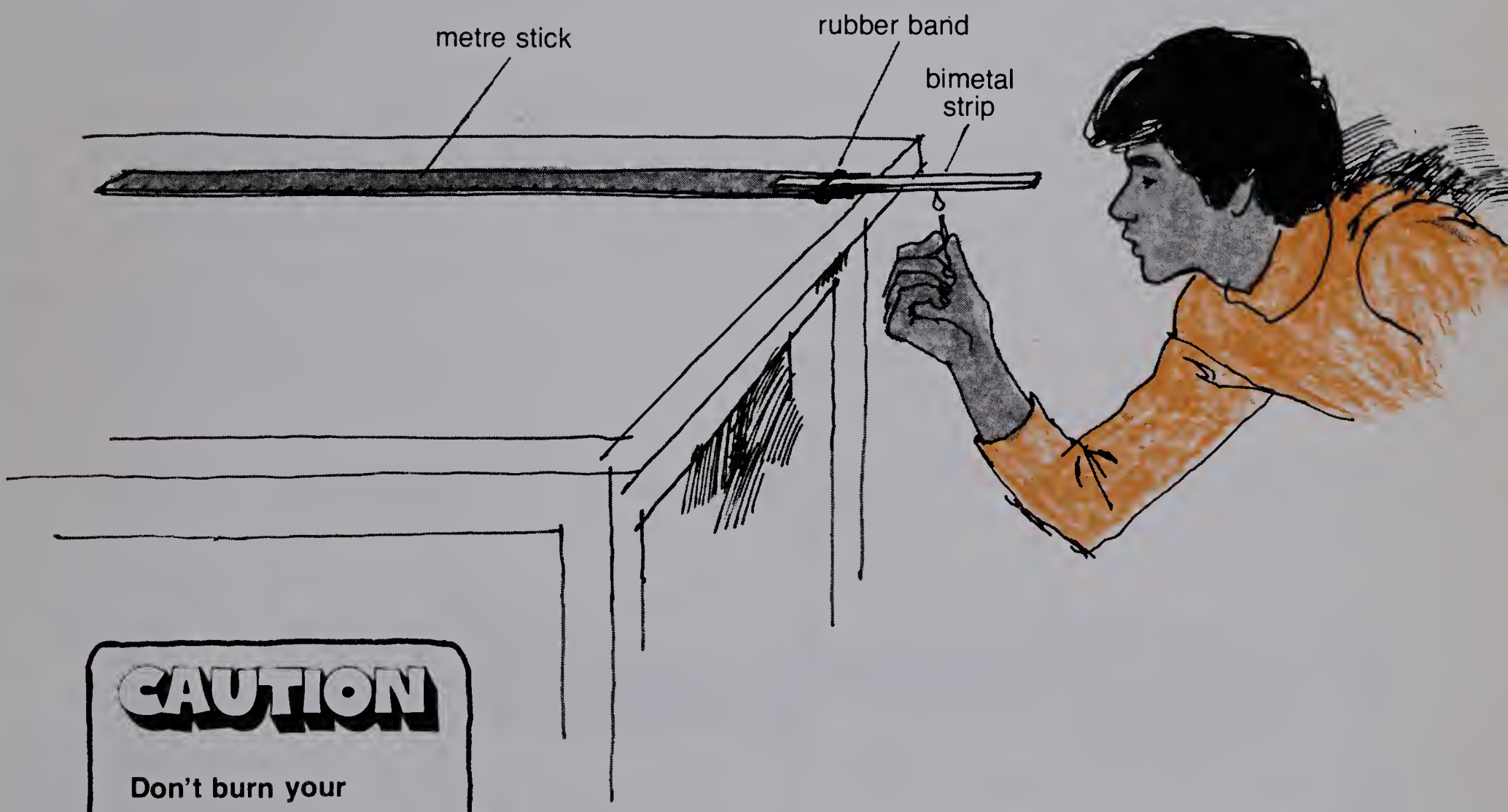
You probably gave some temperature from 18°C to 24°C (65°F to 75°F). Different people feel comfortable at different temperatures. A person may be comfortable at a certain temperature at one time and at some other temperature at another time. But regardless of the temperature you gave, there are times when you have to do something to maintain it. Sometimes you have to add heat; other times you have to take heat away.

Most air-conditioning and heating systems are controlled by thermostats. That means you set a thermostat at the temperature you want, and the system is turned on and off to keep that temperature.

How does a thermostat work? To find out you will need the following:

bimetal strip
rubber band
metre stick
desk or table
match

A. With a rubber band, attach the bimetal strip to the metre stick as shown. Place the metre stick on a table or desk so that the bimetal strip is horizontal.



CAUTION

Don't burn your finger in Step B.

B. Put your eye at the same level as the bimetal strip. Light a match and hold it under the center of the strip for a few seconds. Put out the match. Continue to watch the bimetal strip as it cools.

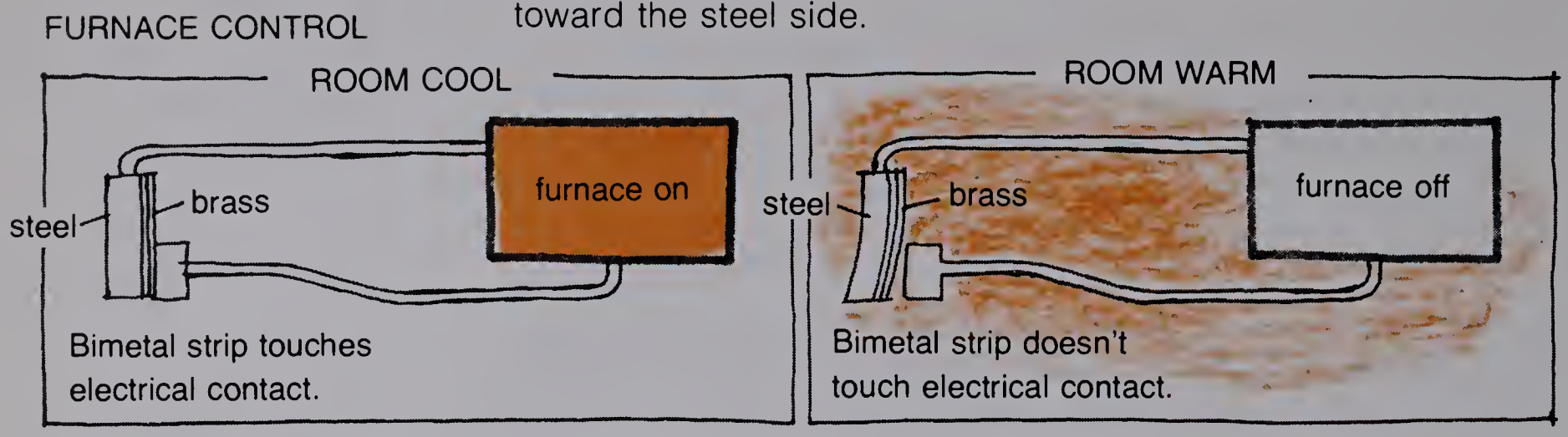
7–3. What happens to the bimetal strip as it heats?

7–3. It bends.

7–4. What happens to the bimetal strip as it cools?

7–4. It straightens out.

A bimetal strip is often made of brass and steel. Brass expands and contracts faster than steel, so heat makes the strip bend toward the steel side.



7-5. Bimetal strip bends and breaks contact, shutting off the furnace.

7-6. Bimetal strip straightens and makes contact, turning on the furnace.

To obtain a thermostat see Advance Preparation p. TM 5.

7–5. What happens when the room warms up?

7–6. What happens as the room cools?

A thermostat can be used to control a heating system. The result is that the temperature in the house stays about the same all the time. A lot of manufactured and living things are self-controlling. Scientists call this kind of self-control *feedback control*.

Feedback is a very important part of all automatic heating systems. Figure 7–1 shows how feedback works in a heating furnace. Start at the upper left and follow the arrows.

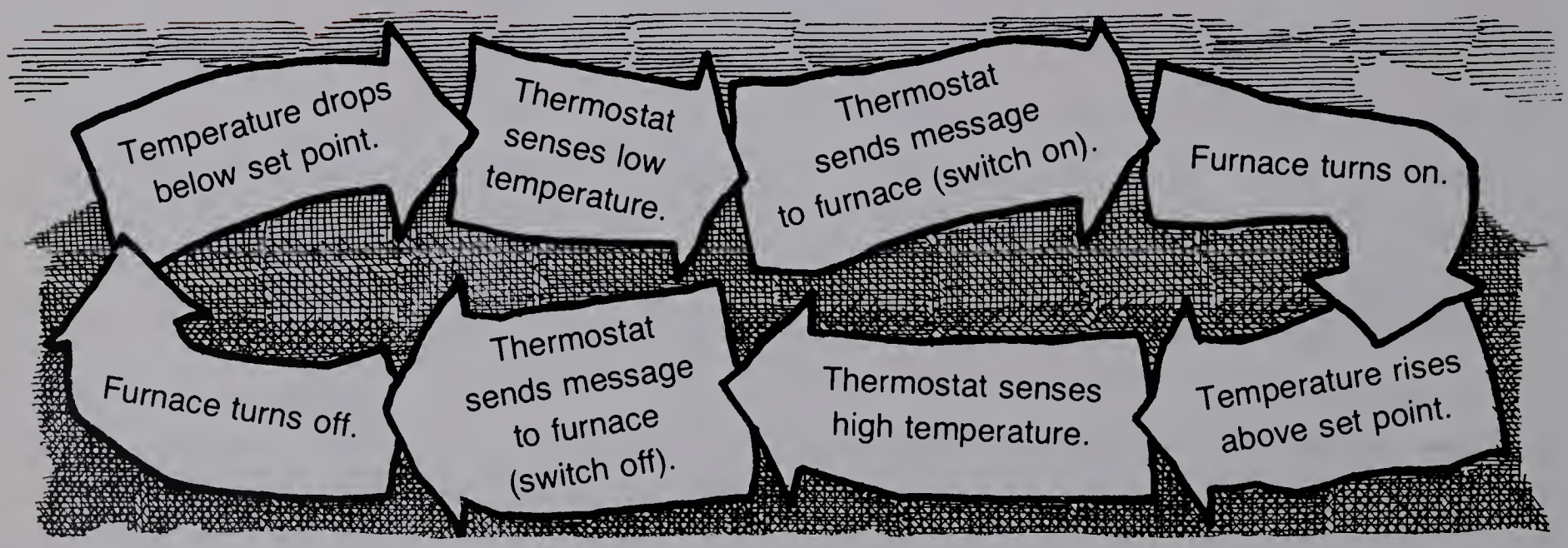


Figure 7–1

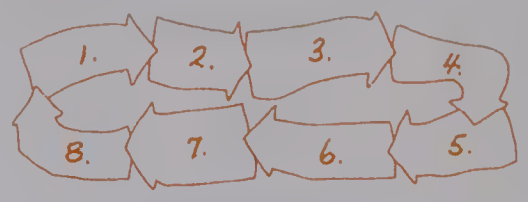
A thermostat on an air conditioner works the same as one on a heating system. It controls the operation of the air conditioner by opening and closing a contact.

7–7. When it's too warm.

★ **7–7. On an air conditioner, is the electrical contact made when it is too warm or too cold?**

✔ 7–8. In your notebook, make a sketch like that in Figure 7–1. Use the blanks to show how a thermostat switches an air conditioner on and off to keep the temperature at a set point. Start by filling in the upper left box with "temperature rises above set point." Then fill in the other boxes.

7-8.



If this is the first time you have run into feedback control, don't worry if its meaning isn't completely clear. You will see it again in other minicourses. However, if you have seen it before and you're still not sure you understand it, you may want to take a look at *Resource Unit 13.* It describes feedback control in more detail.

1. Temperature rises above set point.
2. Thermostat senses high temperature.
3. Thermostat sends message to air conditioner (switch on).
4. Air conditioner turns on.
5. Temperature drops below set point.
6. Thermostat senses low temperature.
7. Thermostat sends message to air conditioner (switch off).
8. Air conditioner turns off.

Staying Comfortable

Have *Resource Unit 13* available to aid students in understanding feedback control.

The same house is shown in two situations below. Suppose the "comfort temperature" in each case is 21°C (70°F).

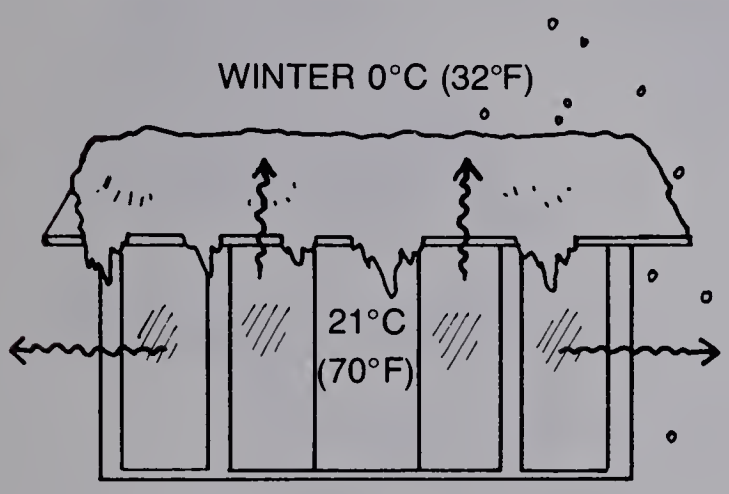


Figure 7–2

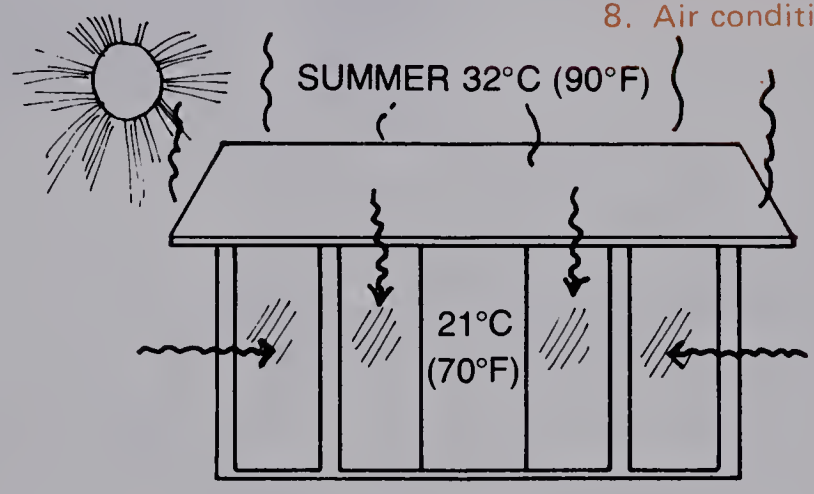


Figure 7–3

✔ 7–9. What is the temperature difference in Figure 7–2?

7-9 21°C (38°F) difference between inside and outside

✔ 7–10. What is the temperature difference in Figure 7–3?

7-10. 11°C (20°F)

In winter, heat inside the house is lost to the colder outside air. In summer, heat is gained from the hotter outside air. The greater the temperature difference, outside to inside, the greater the amount of energy used by the heating or cooling system to keep the inside temperature constant.

★ **7–11. Suppose you set the thermostat lower and decrease the time the heating system is on by a third. What effect will this have on the energy used?**

7-11. Energy consumption will decrease by 1/3.

Staying comfortable takes energy. That's true whether you have to add heat to stay warm or take away heat to keep cool.

ACTIVITY EMPHASIS: Refrigerators and air conditioners are similar in operation.

Activity 8

Keep Cool

People have used heat in their homes for centuries.



MATERIALS PER STUDENT UNIT

None.



First simple fuels like wood, peat, and coal were burned in the middle of living rooms. Now, fuels like natural gas, fuel oil, and electricity are used for stoves, furnaces, radiant heaters, and heat pumps.

Only recently have people been able to cool their homes.



Before air conditioning, people sweltered when it got hot, or they moved, at least temporarily, to cooler places.



Today we take air conditioning for granted, but even keeping foods cool was not easy in the past. The ancient Egyptians cooled their drinking water and other beverages by evaporation (Figure 8–1). An "ice box," like that in Figure 8–2, depended on ice that was cut from lakes in the winter.



Figure 8–1

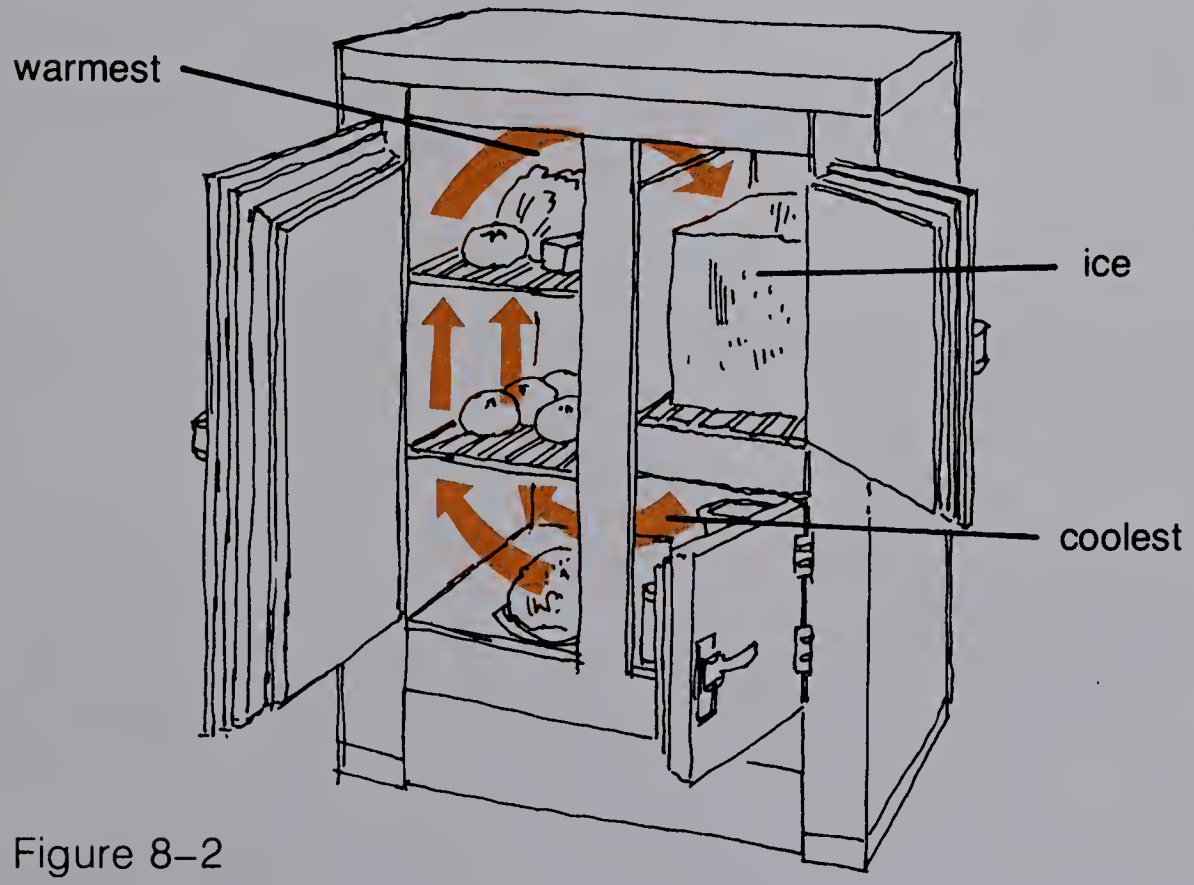


Figure 8–2

Ice Boxes are still in use in areas of northern Canada. Ice is cut from lakes in the winter and packed in sawdust.

✔ 8–1. Why wouldn't the primitive cooling in Figure 8–1 be effective on very humid days?

8-1. There would be little or no evaporation.

✔ 8–2. What important by-product of the ice box had to be taken care of regularly?

8-2. Water from the melted ice.

Electric refrigerators and air conditioners are similiar in operation. In most cases a substance called *Freon* is used as the refrigerant. Figure 8–3 explains both devices.

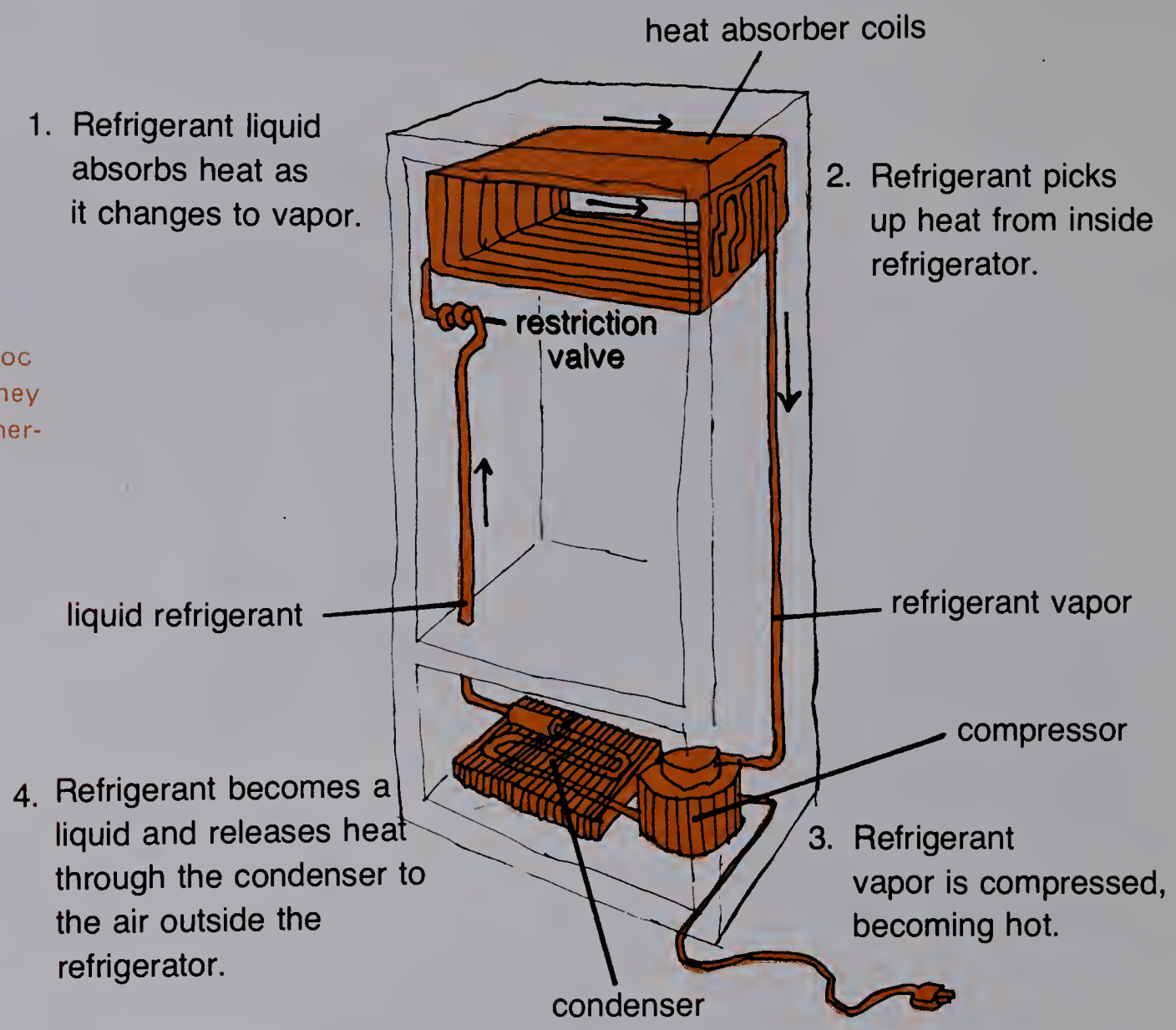


Figure 8–3

You can see that the refrigerant is condensed or expands, releases or absorbs heat. That's the way cooling occurs—heat is absorbed from one place and released to another.

Gases absorb heat energy and coc off their surroundings when they expand. Gases give off heat energy when they are liquified.

★ **8–3. In a refrigerator what happens in the**
a. compressor?
b. condenser?
c. absorber?

8-3. (a) Refrigerant is compressed.
(b) Refrigerant gives up heat and is liquified.
(c) Refrigerant picks up heat.

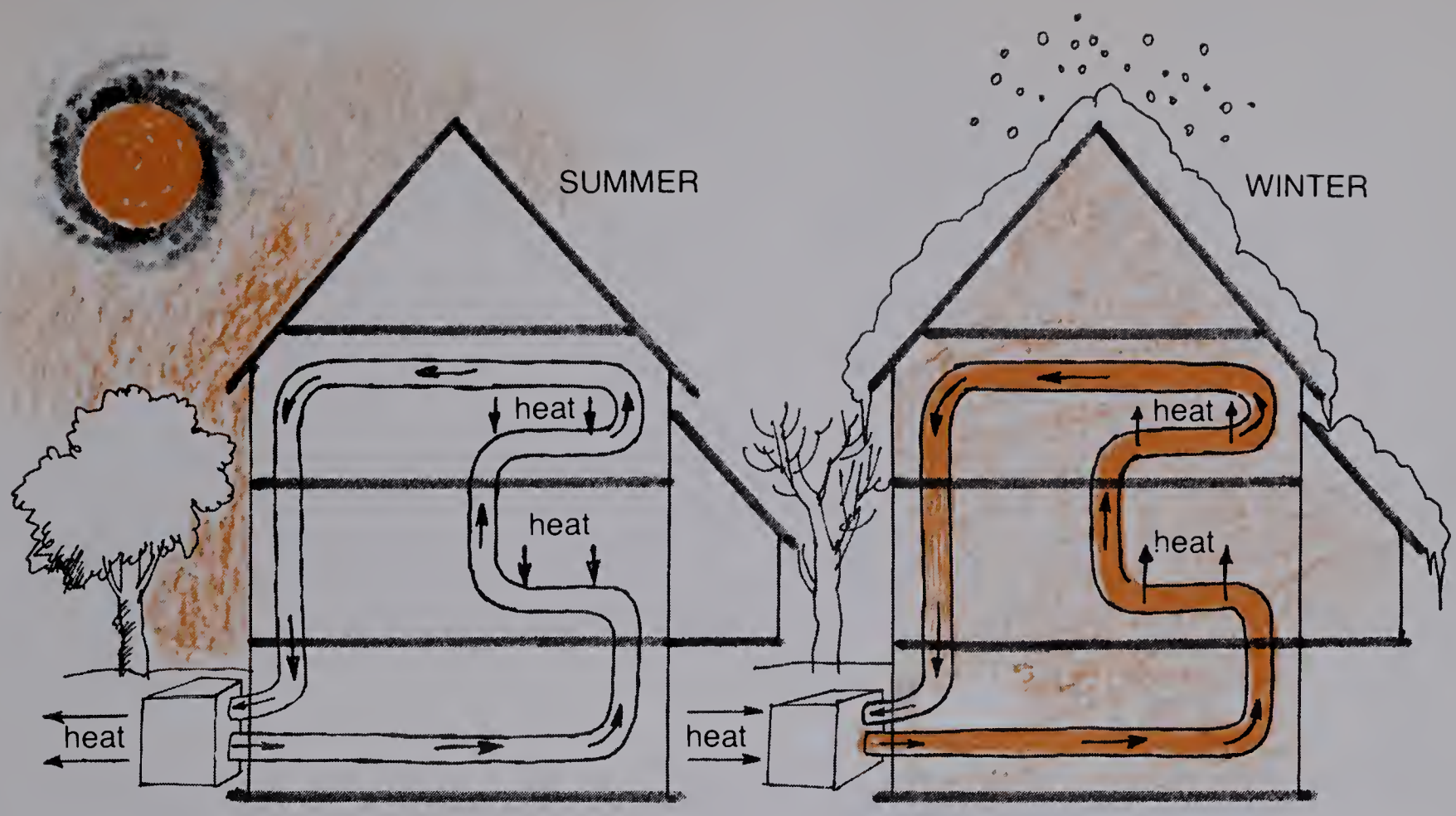
✔ 8–4. In an air conditioner, where does the refrigerant get the heat that it carries to the outside?

8-4. From the air in the room.

✔ 8–5. Explain why you can't cool the kitchen by keeping the refrigerator door open.

8-5. The heat given off by the condenser more than makes up for the cooling of the absorber coils.

Some modern heat pumps can do double duty. They are air conditioners in the summer and heaters in the winter.



Heat from compressing the refrigerant is released outside, while heat is picked up inside.

Heat from compressing the refrigerant is released inside, while heat is picked up outside.

8–6. Where is the air cooled in an air conditioner?

8-6. Absorber, or cooling coils.

ACTIVITY EMPHASIS: Heating and cooling costs can be reduced by properly adjusting the thermostat and using insulation. Investigate effect of insulation on cooling water.

Cutting Energy Costs



What is the monthly bill for utilities in your household? Amounts between $30 and $80 a month are quite common. That adds up to a lot of money in a year.



MATERIALS PER STUDENT UNIT

beaker, glass, 250-ml
3 thermometers, Celsius, 0-110 degrees
watch or clock with second hand
small piece of plastic foam, 10 cm X 10 cm
small piece of plastic foam with hole in center, 10 cm X 10 cm
cloth or paper towel
cup, plastic foam, same size as 250-ml beaker
cup or can, metal, same size as 250-ml beaker
large pan

Resource Unit 14

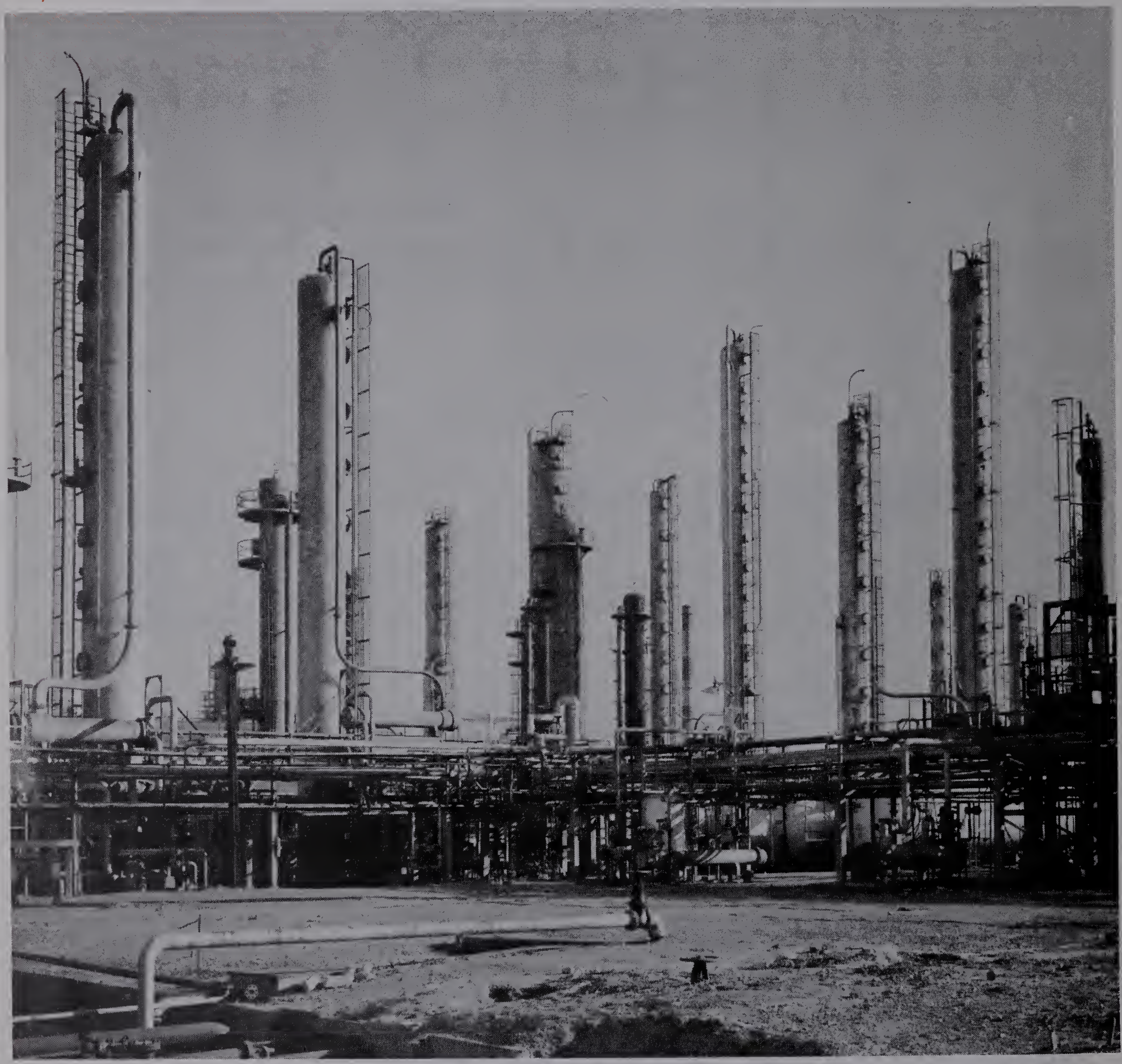
9-1. By lowering thermostat settings in winter and raising them in summer; using less hot water; turning off lights; drying clothes outdoors; etc.

9-2 Answers will vary but originally most came from the sun.

The cost of energy is likely to keep going up. The money you spend buying energy is money you can't spend on something else. Keeping your home either warm or cool takes about half of the total energy used by your family.

✔ 9–1. How do you think energy can be saved at home?

✔ 9–2. Where do we get energy?



Natural gas, fuel oil, gasoline, and heating oil are among the products from a refinery.



Hydroelectric generators provide much of the electric energy used in some areas.



Once, wood was the principal source of energy for heating and cooking.



There are still huge reserves of good quality coal in the United States.

Most of the energy we use today comes from our natural surroundings. It is possible to use up this type of energy. Knowing how to keep certain things cool and other things warm will help prevent an energy shortage.

In summer, an air conditioner can cool the inside of a house. It moves heat out. But heat keeps getting back into the house, through the walls, windows, and roof as shown in Figure 9–1.

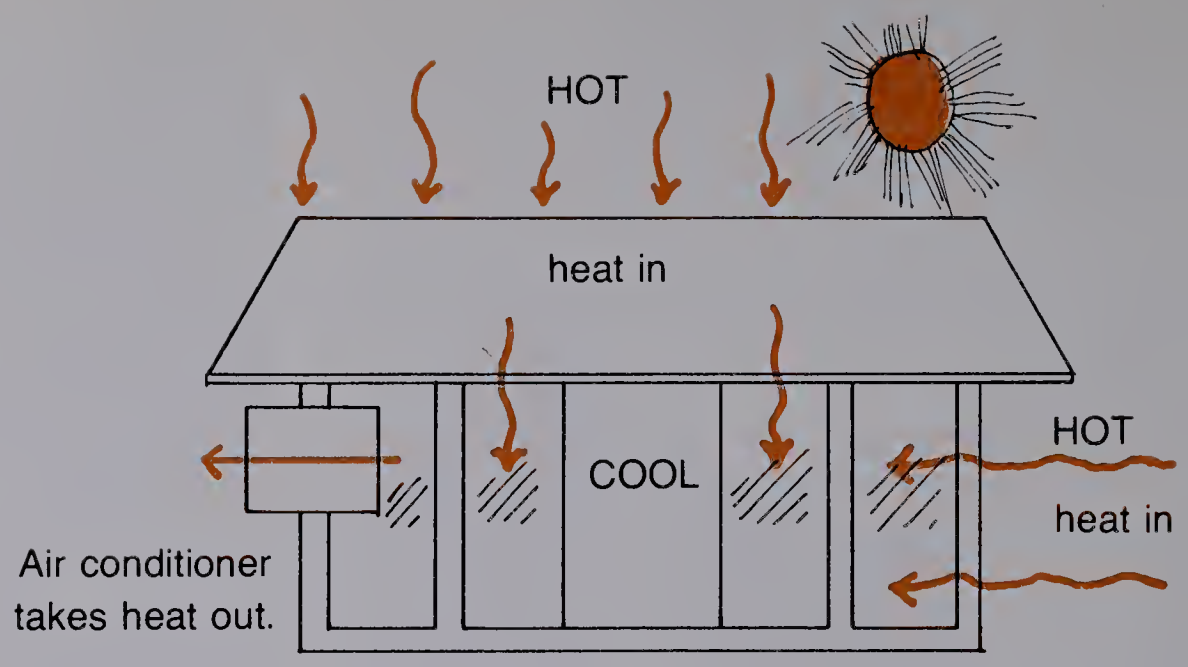


Figure 9–1

In winter, a heater puts heat energy into the house. But, all the time, heat energy gets out of the house. It leaves through the walls, windows, floors, and roof as shown in Figure 9–2.

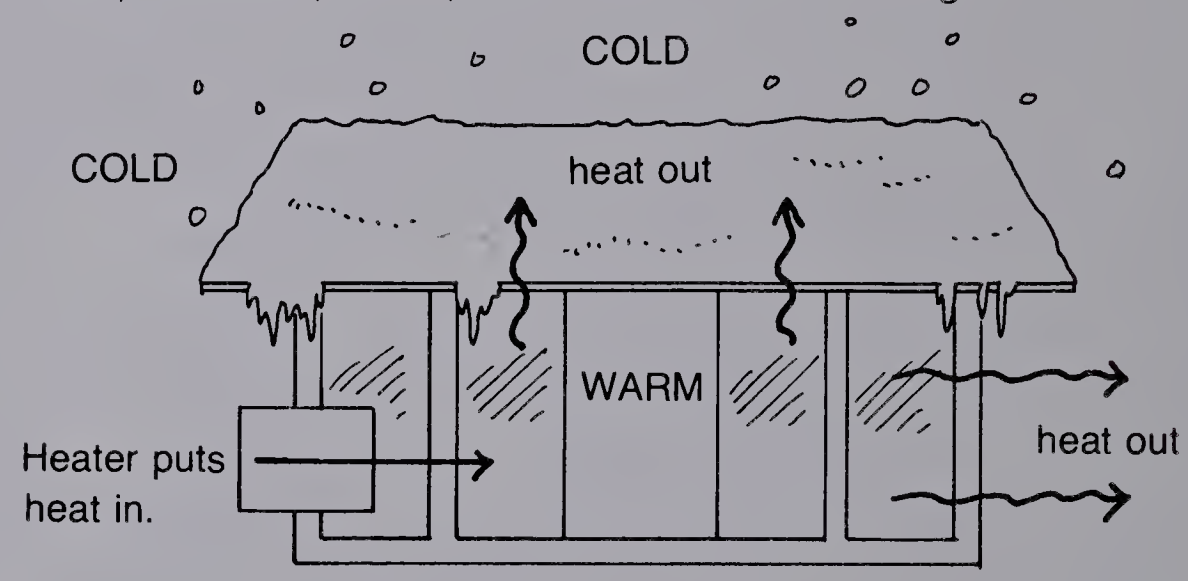


Figure 9–2

9-3. Insulate so the heat can't get out or in.

9–3. What is an obvious way to cut heating and cooling bills?

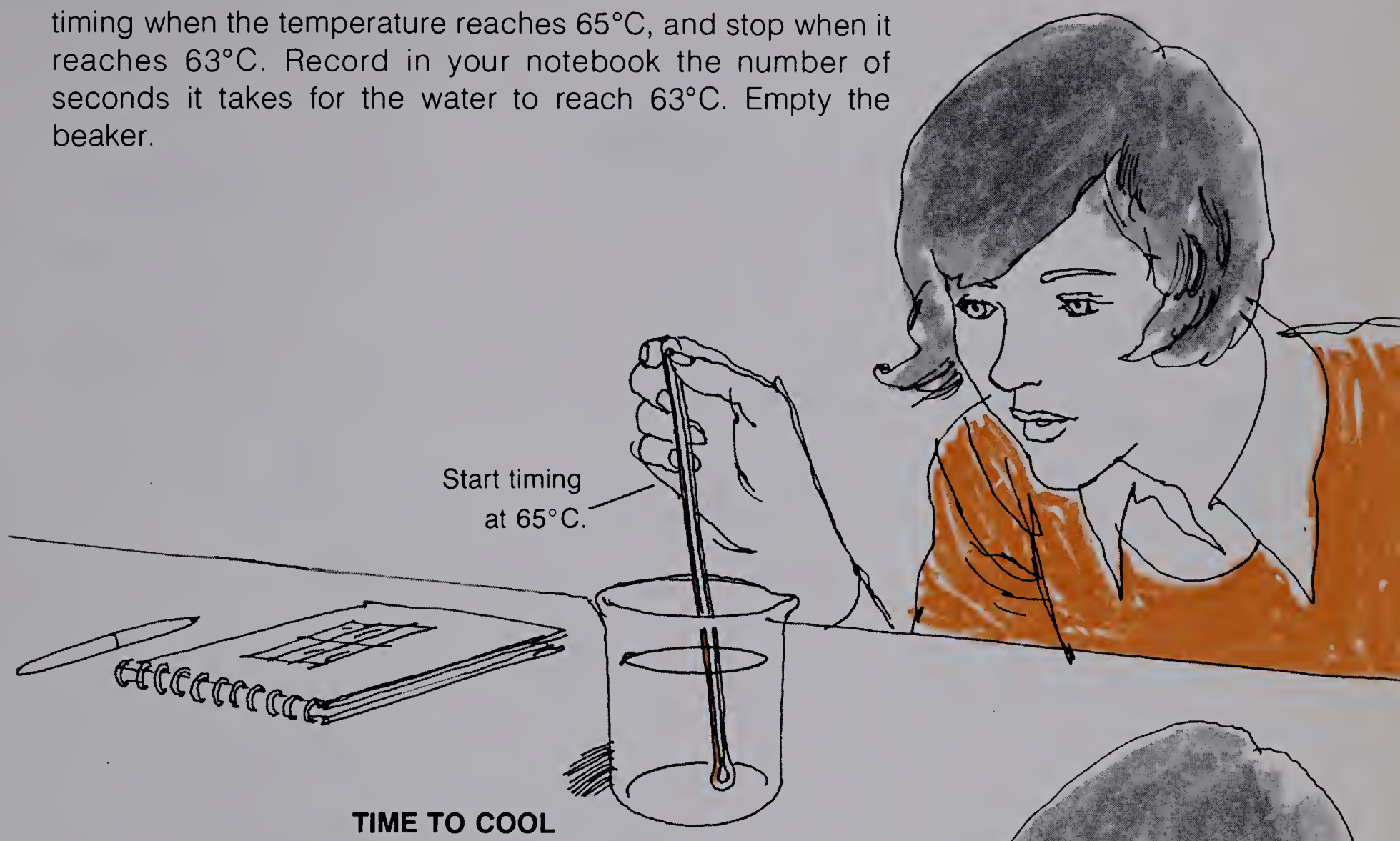
This investigation may give you some clues about how heating and cooling bills can be cut. You will need 30 minutes and the following:

beaker, glass, 250-ml
thermometer, 0–110°C
watch or clock with second hand
small piece of plastic foam, 10 cm × 10 cm
small piece of plastic foam with hole in center, 10 cm × 10 cm
cloth or paper towel

Have *Resource Unit 14* available to aid students in using the thermometer.

Be sure you know how to use the thermometer. If you aren't sure, see *Resource Unit 14* now, before you begin Step A.

A. In your notebook, make a table like that in Figure 9–3. Fill a beaker about ⅔ full of hot water, as hot as you can get it from the hot-water faucet. Put a thermometer into the water. Start timing when the temperature reaches 65°C, and stop when it reaches 63°C. Record in your notebook the number of seconds it takes for the water to reach 63°C. Empty the beaker.

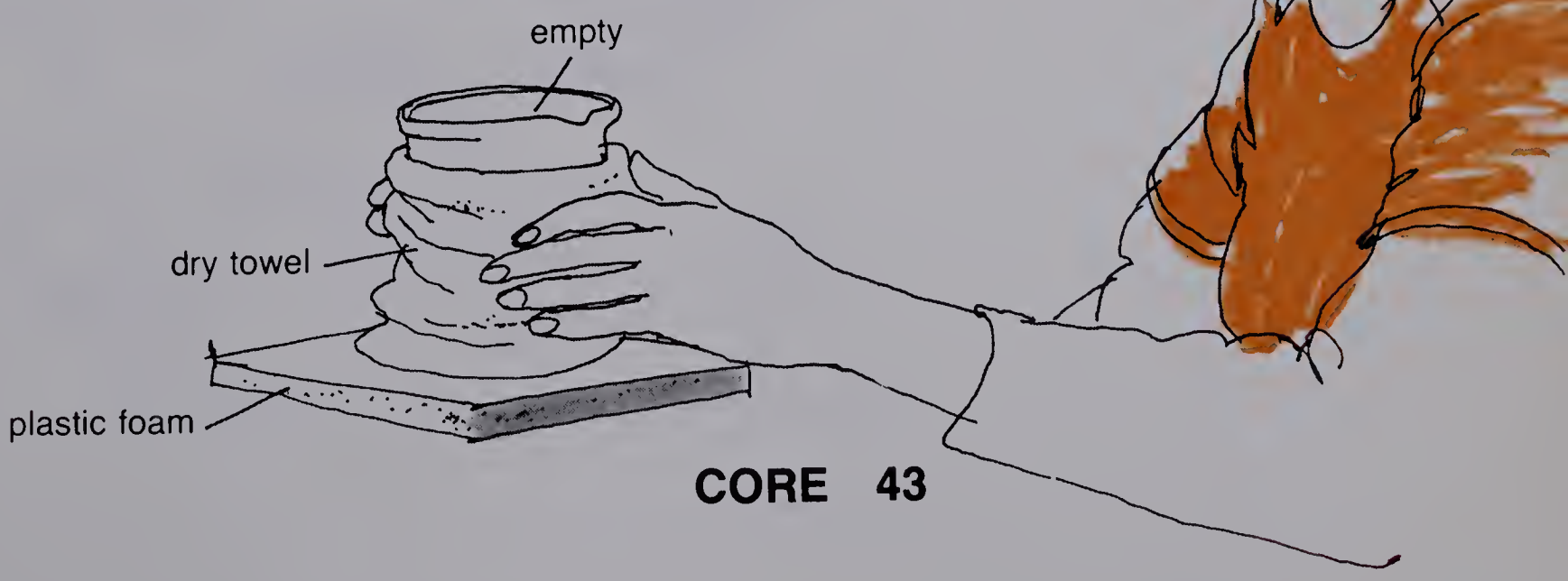


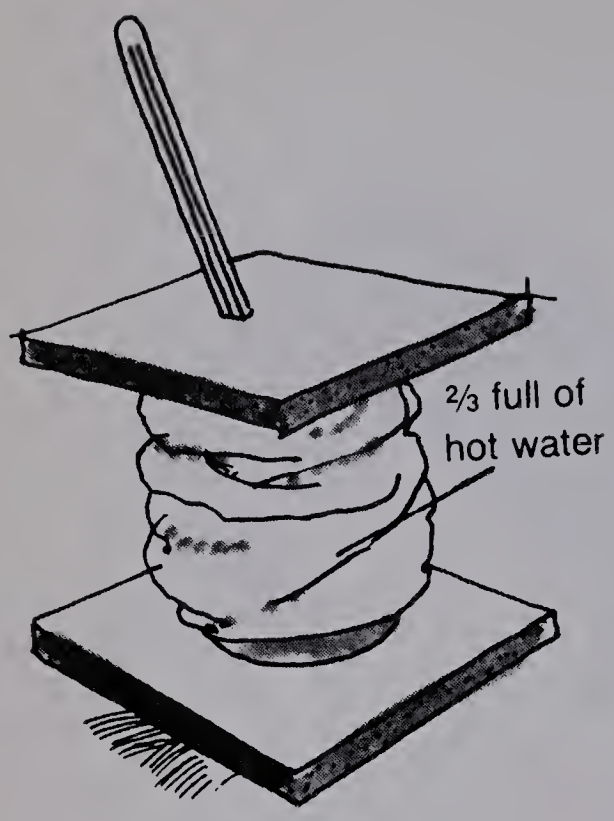
TIME TO COOL

	TIME (IN SEC) TO COOL FROM 65°C TO 63°C
Beaker not wrapped	
Beaker wrapped	

Figure 9–3

B. Stand the beaker on a piece of plastic foam. Wrap the beaker snugly with a dry cloth or paper towel.





C. Fill the beaker about ⅔ full of hot water. Cover with a piece of plastic foam with a hole in the center. Put the thermometer through the hole. Start timing when the temperature drops to 65°C and stop when it reaches 63°C. You may have to pull up the thermometer a few centimetres when you make readings. Record the time in your notebook.

✔ 9–4. In which case did heat leave the water faster?

9-4. When the beaker was not wrapped.

✔ 9–5. Does insulation make a difference in heat transfer?

9-5. Yes.

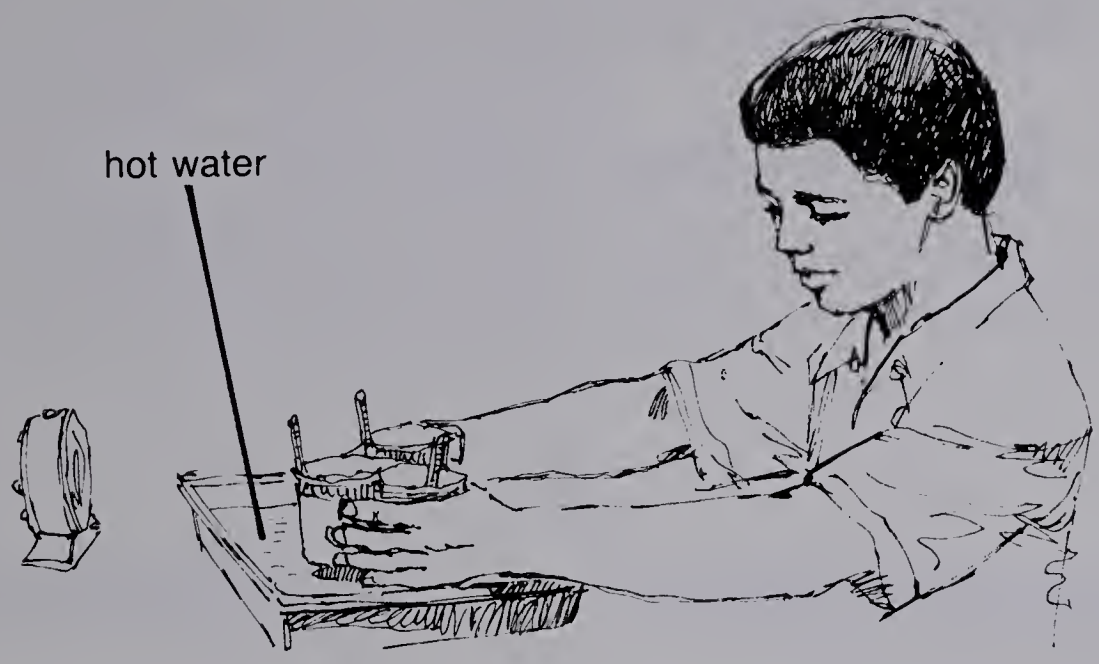
Insulation keeps heat from getting out. Does it also keep it from getting in? You can find out fairly quickly. You will need the following items:

pitcher or other container
beaker, glass, 250-ml
cup, plastic foam, same size as beaker
cup or can, metal, same size as beaker
3 thermometers, 0–110°C
watch or clock with second hand
large pan

A. Fill the beaker, plastic foam cup, and metal cup about ⅔ full of cool water (25°C or below). Put a thermometer in each container. The three temperatures should be the same.



B. Fill the pan with hot water (65°C or above) to about half the height of the beaker. All at one time, set the beaker, metal cup, and plastic foam cup, with their thermometers, into the hot water. At the end of one minute, read the three thermometers.



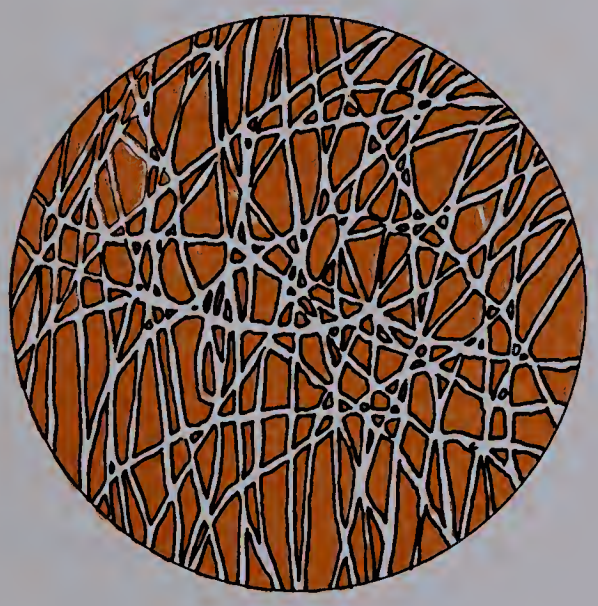
✔ 9–6. Which thermometer showed the greatest change in temperature? The least change?

9-6. Greatest: metal can, Least: plastic foam cup.

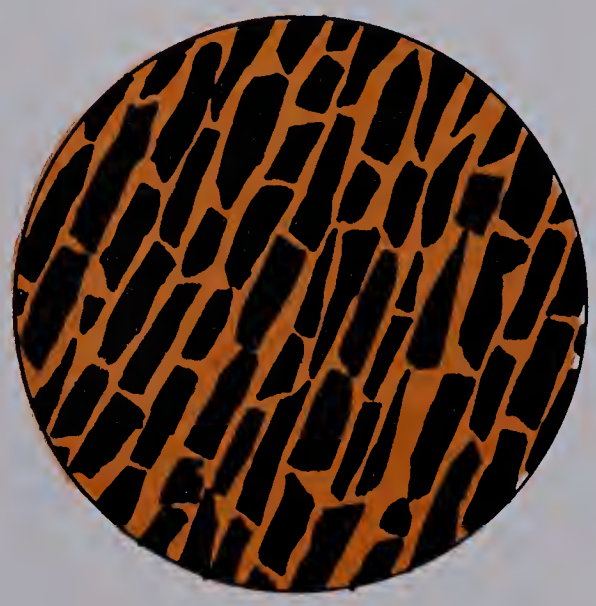
★ **9–7. Rank glass, metal, and plastic foam in the order of their insulating qualities.**

9-7. Plastic foam is best, then glass, and finally metal.

Plastic foam is full of little air holes. When air can't move around, it makes a good insulator.



Fiberglass has lots of air spaces.



Cork is a light, porous wood.

✔ 9–8. Does ordinary metal have air holes? 9-8. No.

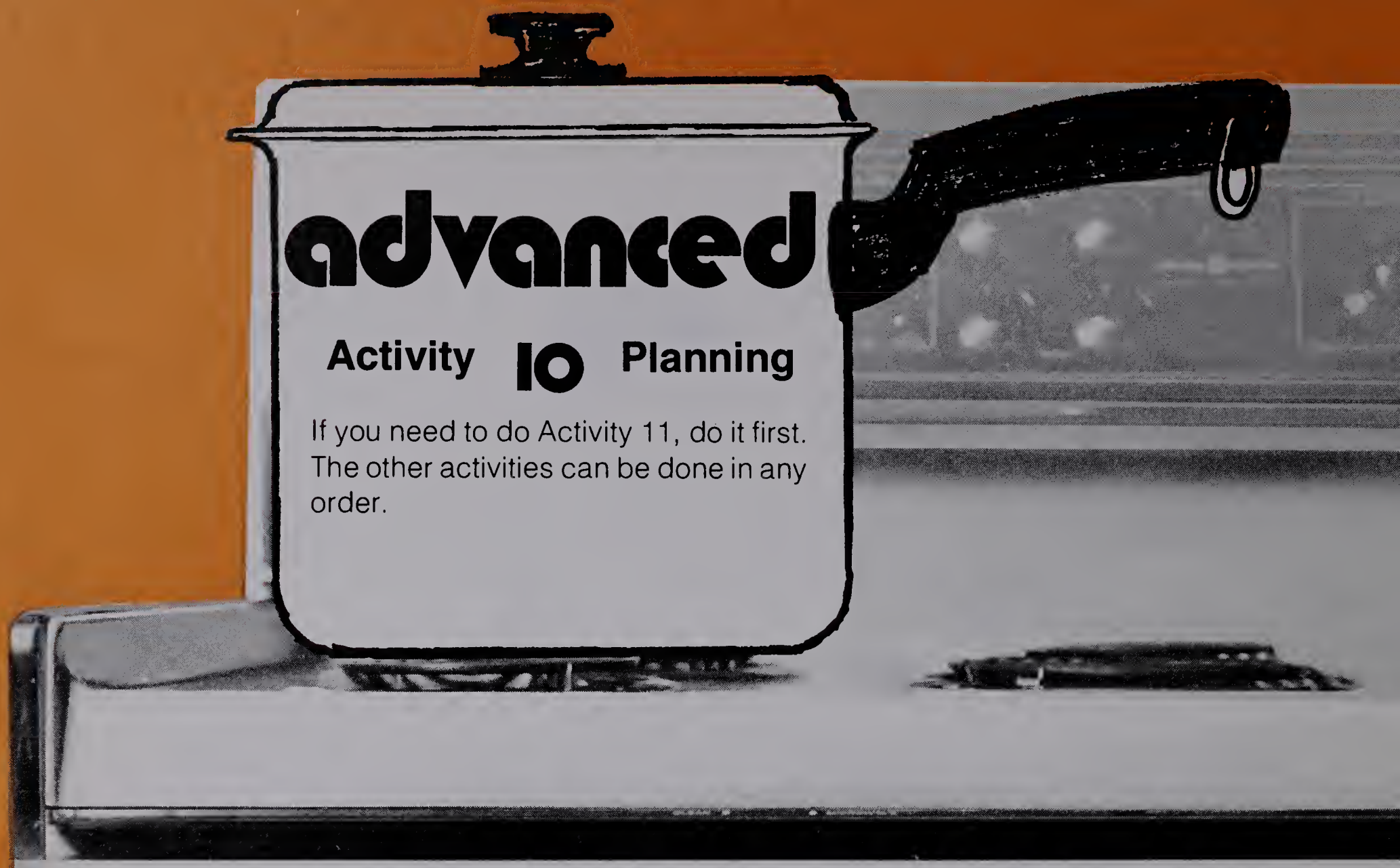
In general, any substance that has air spaces is a good insulator. Little air spaces insulate. They can cut energy costs for you.

✔ 9–9. Why does loosely woven cloth keep a person warm?

9-9. It has trapped air.



Explain that some types of plastic foam are not suitable for use as home insulation, since they are flammable and/or give off poisonous fumes when burned.



advanced

Activity 10 Planning

If you need to do Activity 11, do it first. The other activities can be done in any order.

Activity 11 Page 48

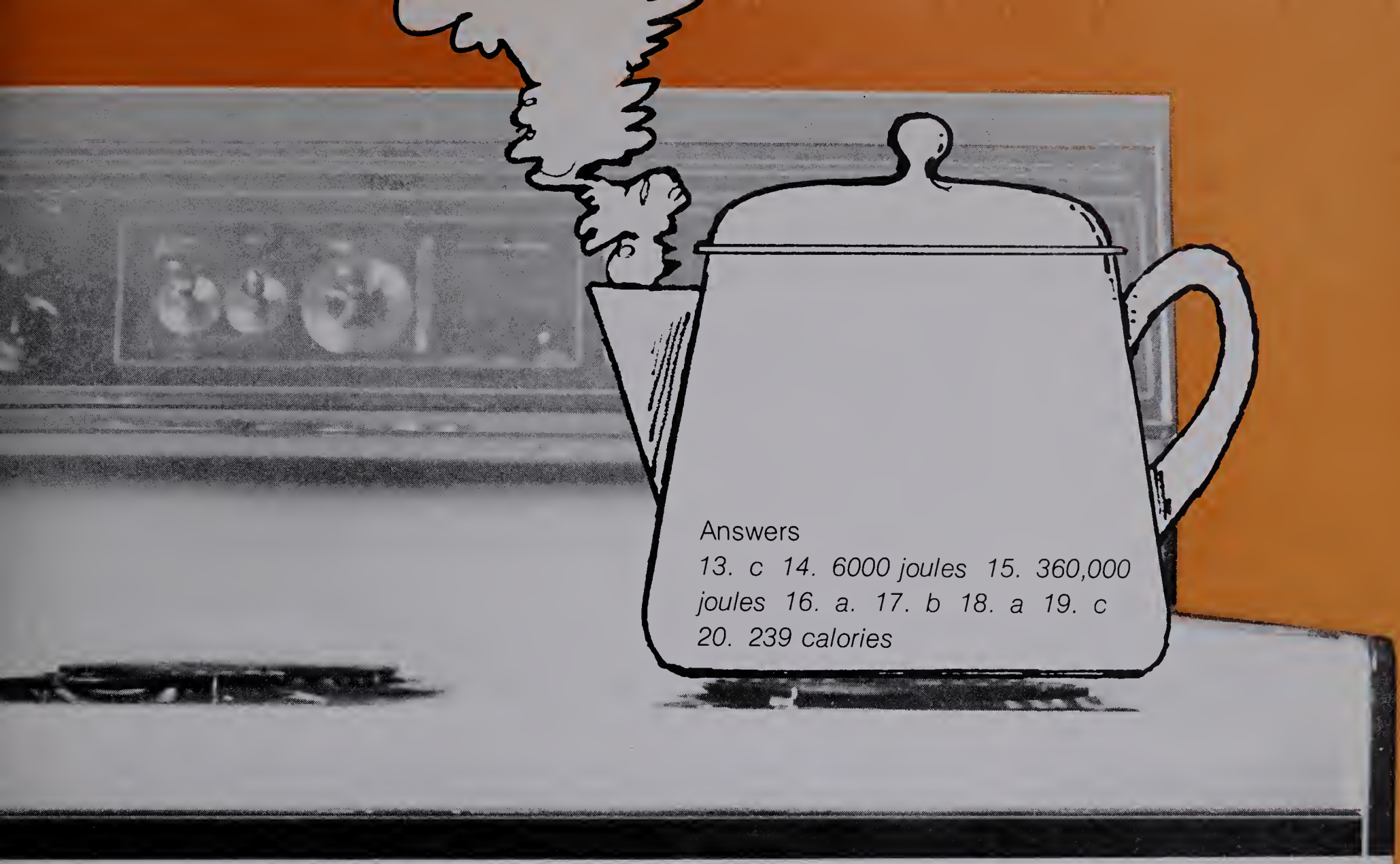
Objective 13: Operationally define a joule in terms of power and time.
Sample Question: What is a joule?
a. a watt
b. a kW h
c. 1 watt × 1 second

Objective 14: Calculate the amount of energy in joules consumed by several common appliances.
Sample Question: How many joules of energy does a 100-watt bulb use in one minute?

Activity 12 Page 50

Objective 15: Calculate the difference in the amount of energy used to heat a quantity of water by electricity and the amount of heat energy given the water.
Sample Question: How many joules of electrical energy are used if it takes six minutes to raise the temperature of 500 g of water from 20°C to the boiling point in a 1000-watt kettle?

Objective 16: Explain the loss in useful energy when converting from electrical to heat energy in a hot-water heater.
Sample Question: In a heater, the input of electrical energy is 180,000 joules, while the output of heat energy is 40,000 calories. A comparison of the input and output shows that
a. heat is lost to the surroundings.
b. heat is gained from the surroundings.
c. the input and output are the same.



Answers
13. c 14. 6000 joules 15. 360,000 joules 16. a. 17. b 18. a 19. c 20. 239 calories

Activity 13 Page 54

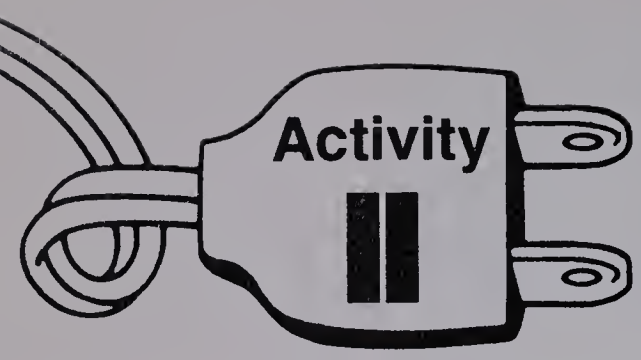
Objective 17: Explain how the kinetic molecular theory is used to describe heat transfer.
Sample Question: The kinetic molecular theory explains conduction of heat in terms of
a. a calorie fluid.
b. molecular collisions.
c. stationary molecules.

Objective 18: In terms of the kinetic molecular theory, describe the motion of air particles as they are heated.
Sample Question: Which of the following mathematical formulas best describes the motion of gas molecules?
a. $KE = \frac{1}{2} mv^2$
b. $E = mc^2$
c. $vt = dm$

Activity 14 Page 58

Objective 19: Describe the experiments of Rumford, Davy, Joule, and Mayer in defining a model for heat.
Sample Question: What did Count Rumford use to show that heat is a form of energy?
a. a paddle wheel that churned water
b. human blood that changed color
c. cannons that gave off heat when bored

Objective 20: Compute the mechanical equivalent of heat.
Sample Question: A rotating frictional device uses 1000 newton metres of mechanical energy in turning. How many calories of heat result if the energy is totally converted?



ACTIVITY EMPHASIS: A kilowatt hour is equivalent to 3,600,000 joules of energy. Scientific notation is used.

Measuring Energy

MATERIALS PER STUDENT UNIT

None.

Power is the rate at which energy is used. If you multiply power by the length of time it is used, you get the total energy produced.

11–1. What is the smallest unit of power you have worked with in this minicourse? 11-1. Watt.

11–2. What is the smallest unit of time you have worked with in this minicourse? 11-2. Second.



Multiplying the smallest units of power and time gives a small unit of energy. It looks like this.

$$1 \text{ watt} \times 1 \text{ second} = 1 \text{ joule}$$

The smallest unit of energy is called a *joule* [JEWL]. A joule is a watt second of energy. It is the amount of energy that an appliance rated at one watt uses in one second.

11–3. How many joules of energy does a 60-watt light bulb use in one second? 11-3. 60 joules

11–4. How many joules does it use in a minute? 11-4. 3600 joules

Get the idea? The number of watts (60) multiplied by the time in seconds (either 1 or 60) gives the energy in joules.

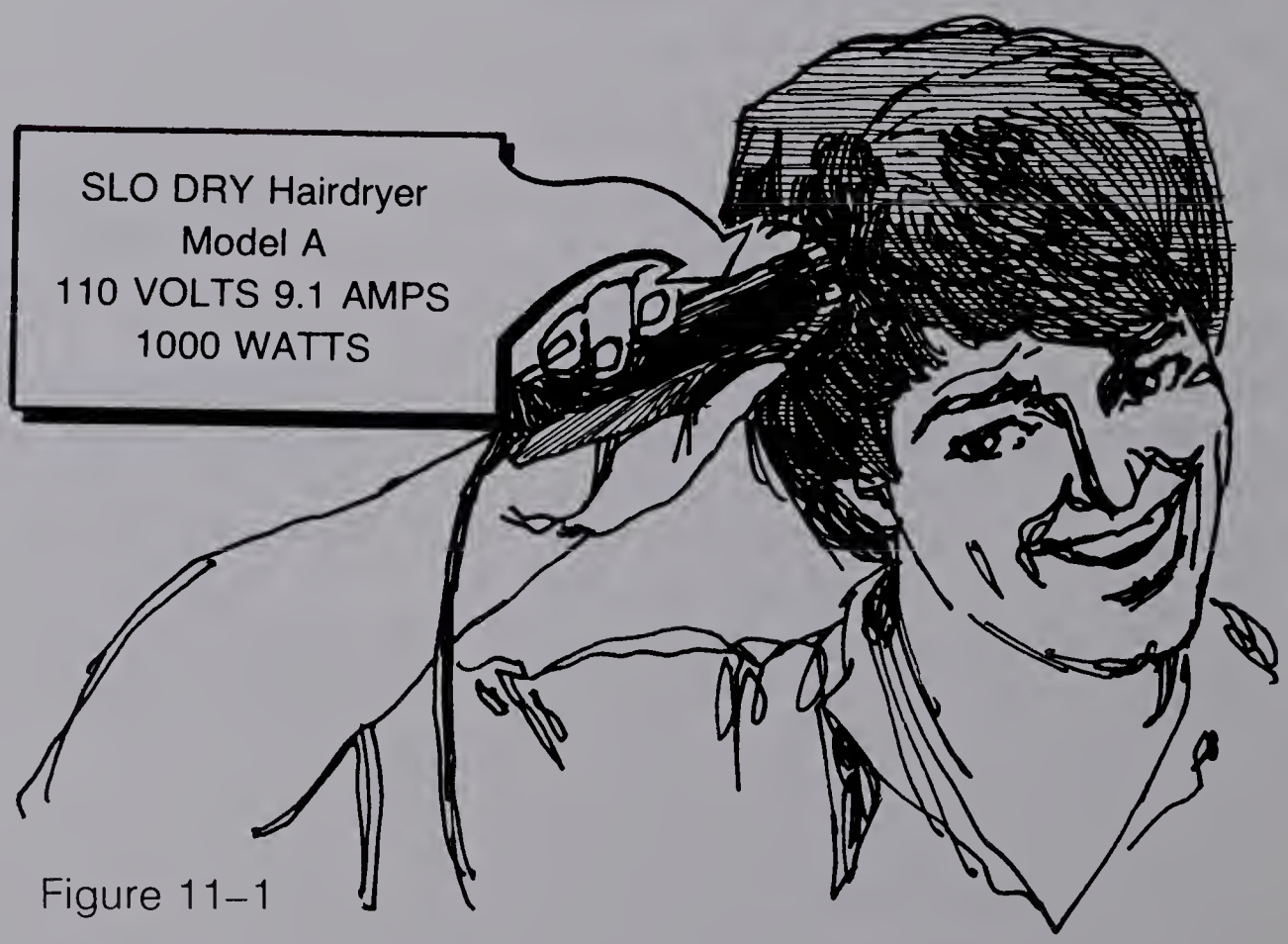


Figure 11–1

✔ 11–5. How many joules of electrical energy are used by the hair dryer in Figure 11–1 in
a. one second?
b. one minute?
c. one hour?

11-5. (a) 1000 joules
(b) 60,000 joules
(c) 3,600,000 joules

Gets to be a big number fast, doesn't it? The joule is too small a unit to conveniently measure household electricity. It's like measuring the distance to the moon in centimeters, or measuring your age in seconds.

The electric company uses kilowatt hours (kW h) as its unit. A kilowatt hour is the amount of energy used in one hour by a 1000-watt appliance.

1 kilowatt hour = 1000 watts for 3600 seconds

1 kilowatt hour = 1000 joules per second for 3600 seconds

1 kilowatt hour = 3,600,000 joules

★ **11–6. One kilowatt hour equals how many joules of energy?**

11-6. 3,600,000 joules

There's an easy way to write big numbers like 3,600,000 joules. It's called *scientific notation,* or powers of ten.

✔ 11–7. Write 3,600,000 joules in scientific notation.

11-7. 3.6×10^6 joules

Check your answer with your teacher. You'll be using powers of ten as you go on in this activity.

The number of joules in a kilowatt hour should look familiar. It's the same number of joules used by the hair dryer in one hour. In one hour, the 1000-watt dryer used a kilowatt hour (kW h) of electrical energy.

$$\text{kW h} = \frac{\text{watts} \times \text{hours}}{1000}$$

11-8. 2.4 kW h

11–8. How many kW h will a 100-watt bulb use in 24 hours?

11-9. 1380 kW h

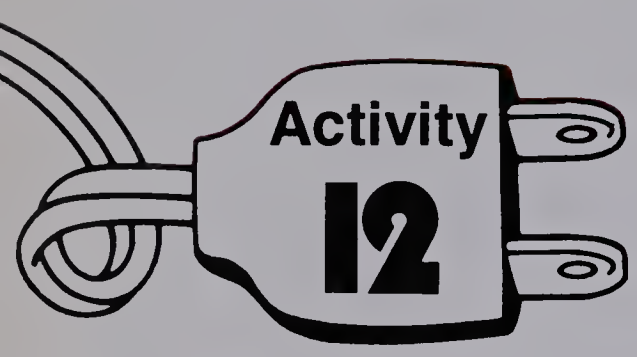
11–9. An electric heating system is rated at 12,000 watts. How many kilowatt hours of energy will be saved, if the thermostat is set so that the system runs 115 hours less per month?

11-10. 4.968×10^9 joules

11–10. In scientific notation, write the number of joules saved in Question 11–9.

11-11. 172,800 joules

★ **11–11. An electric clock is rated at 2 watts. How many joules of energy will it use in a day?**



ACTIVITY EMPHASIS: Investigation to show the equivalence between heat energy and electrical energy.

Heat Energy

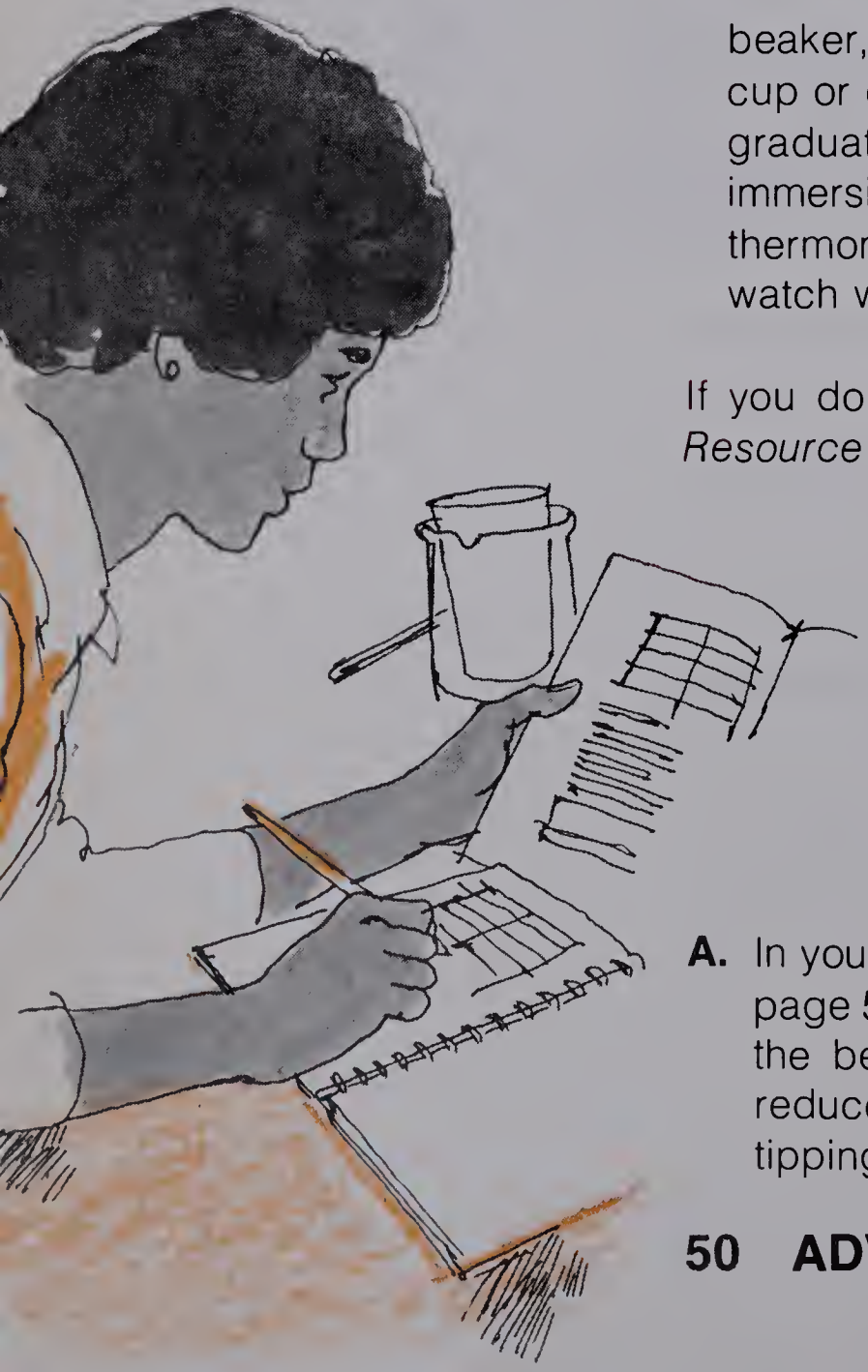
For an alternative way to do this investigation see Advance Preparation, p. TM 6.

How much heat energy can you get from an electrical heater? You can find out by using electricity to heat water, and measuring how much electrical energy was used and how much heat was produced. You will need a partner and the following:

beaker, 250-ml
cup or can holder, plastic foam
graduated cylinder, 100-ml
immersion heater, 75–150 watt, 110-volt
thermometer, 0–110°C
watch with second hand

Have *Resource Unit 5* available to aid students in using the graduated cylinder.

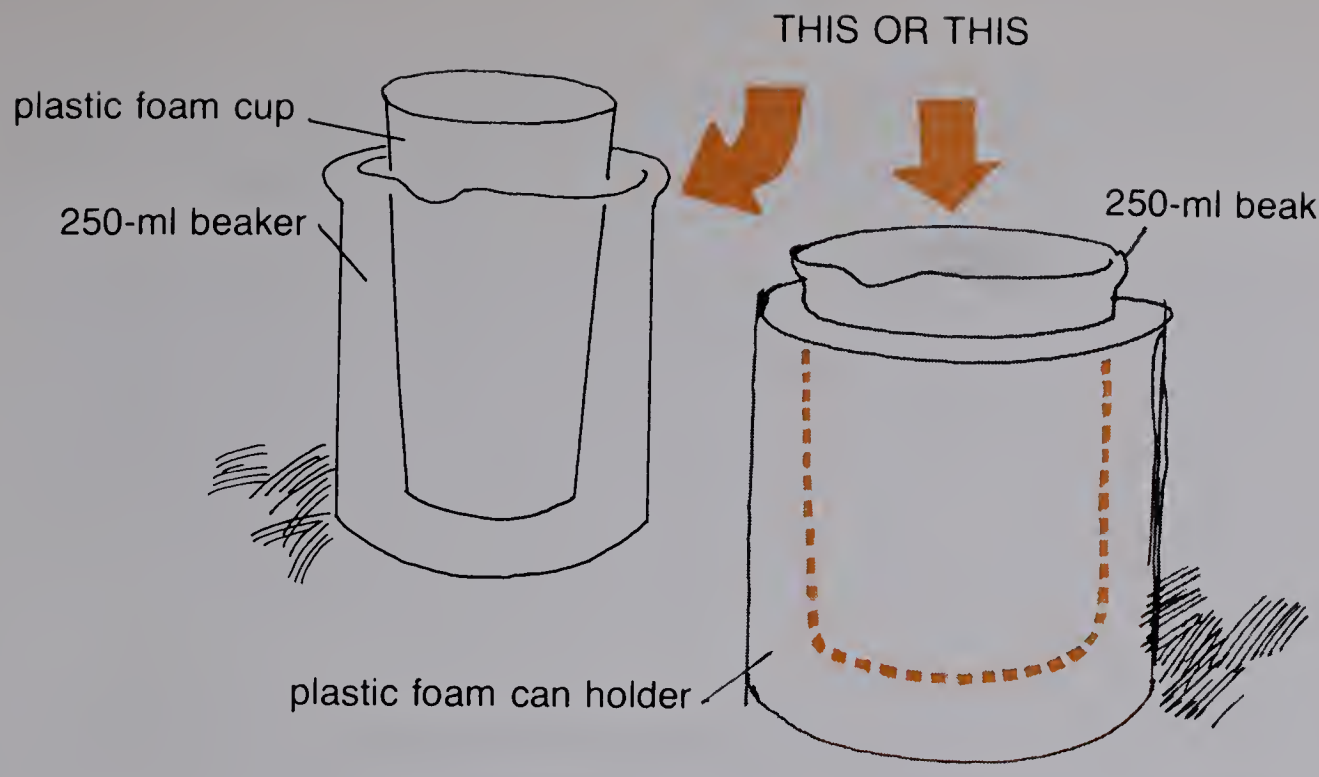
If you don't know how to use the graduated cylinder, refer to *Resource Unit 5*.



CAUTION

Don't plug in the immersion heater until the instructions tell you to.

A. In your notebook make a table like the one in Figure 12–1 on page 52. Set the plastic foam cup inside the 250-ml beaker, or the beaker inside a plastic foam can holder. The cup will reduce heat loss, and the beaker will keep the cup from tipping over.

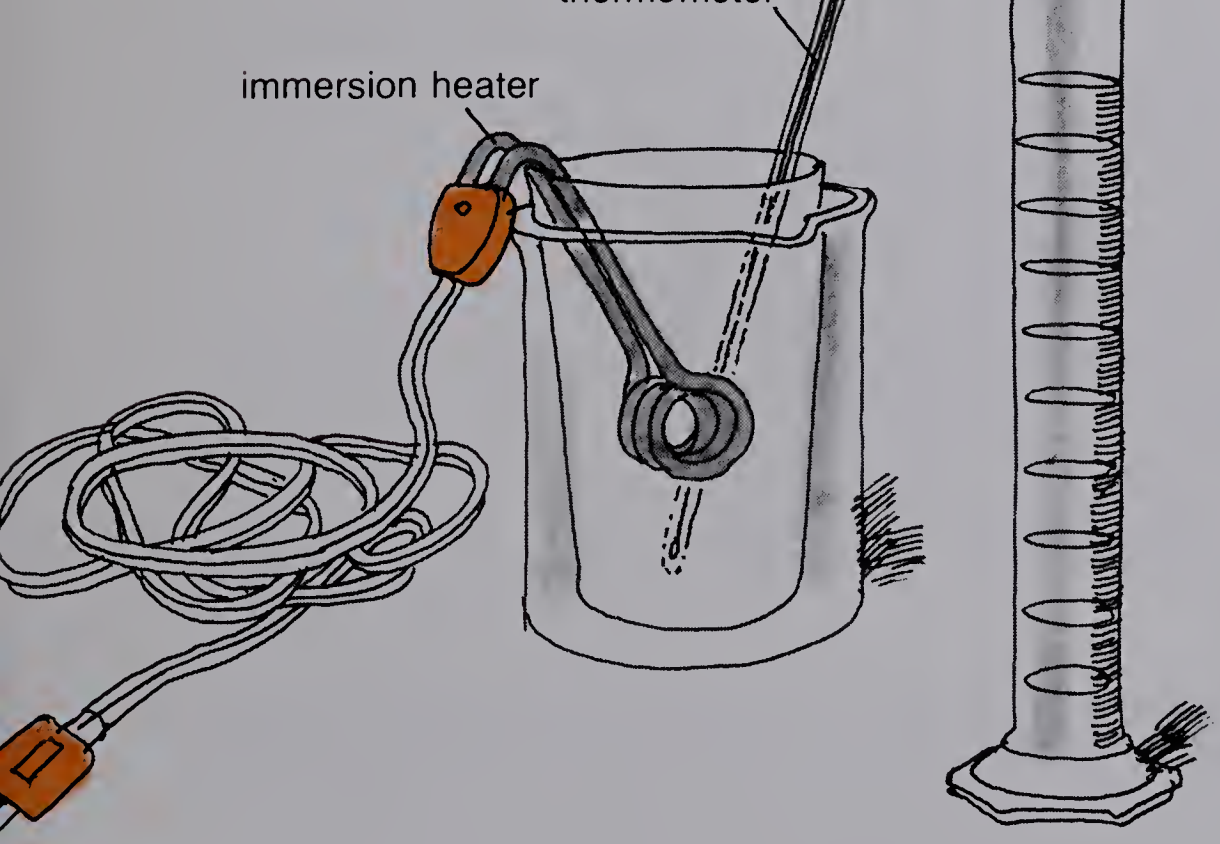


MATERIALS PER STUDENT UNIT
beaker, 250-ml
cup or can holder, plastic foam
graduated cylinder, 100-ml
immersion heater, 75–150 watt, 110-volt
thermometer, Celsius, 0–110°
watch with second hand
Resource Unit 5

B. Add 150 ml of *cold* water to the cup or beaker. Record the volume of water in your table. Now stand the immersion heater and the thermometer in the cup or beaker. Be sure the heating coil is completely covered with water. Record the temperature of the water in your table.

Caution students not to let the thermometer touch the immersion heater.

If the heating coil is not submerged in a liquid when the heater is plugged in, it is likely to burn out within a few minutes.





C. Plug in the heater and immediately record the time. One partner should watch the time and unplug the heater in exactly 2 minutes (120 seconds). The other partner should stir the water and read the temperature. In 2 minutes pull the plug. Read and record under "final temperature" the highest temperature of the water. Also record the final time and the wattage rating of the heater.

COMPARISON OF ELECTRICAL ENERGY AND HEAT ENERGY

ELECTRICAL ENERGY	HEAT ENERGY
Voltage = (?) volts	(?) °C end
Current = (?) amperes	(?) °C start
Power = (?) watts	(?) °C change
Elapsed time = (?) seconds	Volume of water = (?) ml

Figure 12–1

12-1. Multiply voltage by amperage.

✔ 12–1. Suppose only voltage and amperage are given on the heater. How would you find the wattage?

Not all the electrical energy was used to heat the water. The thermometer, the containers, and the heater itself were also heated. And, even though you used plastic foam containers, some of the heat leaked out. This loss of heat to the surroundings became greater as the water temperature increased. (See Figure 12–2.)

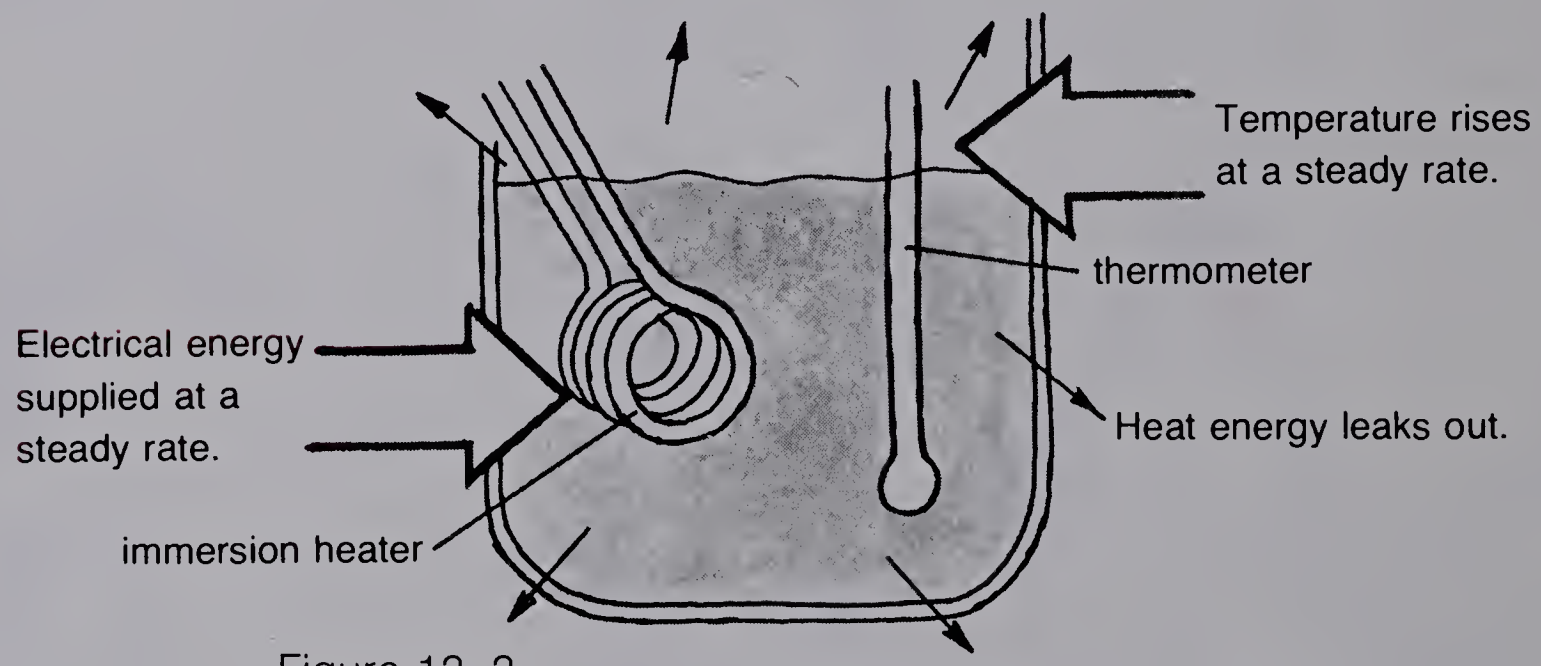


Figure 12–2

12-2. From the surface of the liquid.

✔ 12–2. In addition to the heat losses to thermometer and containers, and through the containers, what other way is heat lost?

Now, compare the electrical energy used and the heat energy produced. How much electrical energy was used? To answer this question, you can use any of these formulas:

electrical energy = joules per second × seconds
(in joules) = watts × seconds
= volts × amperes × seconds

✔ 12–3. From the data in your table, calculate the number of joules of electrical energy used in your investigation.

12-3. Answers will vary, depending on wattage of immersion heater.

Heat energy is usually measured in calories. One calorie is the amount of energy needed to raise the temperature of one gram of water by one degree Celsius. Using the calorie, it's easy to calculate the amount of heat energy absorbed by the water up to its boiling point at 100°C. So, for water—

calories = grams of water × degrees Celsius

To calculate the heat energy absorbed during your investigation, you need to know how many grams of water you heated and the temperature change of the water. You can get this information from your table, if you know that one millilitre of water weighs one gram.

✔ 12–4. Collect the data called for in Figure 12–3 from your earlier work. List it in your notebook.

12-4. Data will vary, depending on wattage of heater.

DATA FOR CALCULATION OF HEAT ENERGY

Volume of water heated =	(?)	ml
Weight of water heated =	(?)	g
Temperature at beginning =	(?)	°C
Temperature after 2 minutes =	(?)	°C
Rise in temperature =	(?)	°C

Figure 12–3

✔ 12–5. How many calories of heat were absorbed according to your data?

12-5. Answers will vary.

Now you have two values for the energy exchanged during your investigation. One is the electrical energy in joules from Question 12–3. The other is the calories of heat energy from Question 12–5.

Did the water absorb all the energy the immersion heater provided? To answer this, you need to change the calories into joules. A calorie is about the same amount of energy as 4.184 joules. In this case, it's close enough to use 1 calorie = 4 joules. It certainly makes the calculations easier!

✔ 12–6. Use 1 calorie = 4 joules to change the calories in Question 12–5 into joules.

12-6. Answers will vary. If using 1 calorie = 4 joules causes the students to get more energy out than was put in, a good discussion may result.

12-7. Answers will vary, but the heat energy absorbed should always be less than the electrical energy used.

✔ 12–7. How did the number of joules of heat energy absorbed compare with the number of joules of electrical energy used?

As a summary, try another problem of electrical-to-heat energy change.

12-8. Difference of 2000 joules (using 1 calorie = 4 joules).

★ **12–8. A 100-watt heater is used for two minutes to heat 100 g of water. The temperature of the water rises 25°C. What is the difference in joules between the electrical energy used and the heat energy absorbed?**

12-9. The difference between the two figures is the amount of heat lost in the apparatus.

★ **12–9. Explain any difference between the two figures you found in Question 12–8.**



Hot Air

ACTIVITY EMPHASIS: Heat energy is usually transferred by conduction or convection. Conduction of heat energy is explained using the kinetic molecular theory.

MATERIALS PER STUDENT UNIT
Bunsen burner
glass rod, 10–15 cm
metal rod, 10–15 cm
test tube, 150–mm
safety goggles

We live in an ocean of air. If the air around our bodies gets too cold, it must be heated to keep us comfortable. Heat, or *thermal energy,* from a stove, radiator, heating coil, or furnace, must be transferred to the air.

How is thermal energy transferred to the air? A series of investigations can show how it happens. You will need about 30 minutes and the following materials:

Bunsen burner	test tube, 20 × 75 mm
glass rod, 10–15 cm	safety goggles
metal rod, 10–15 cm	

If you have not used a Bunsen burner, do *Resource Unit 17* before you begin Step A.

A. Hold one end of a metal and one end of a glass rod in the flame of a Bunsen burner. Hold the rods until one of them becomes uncomfortably warm. Then lay them in a safe place to cool.

CAUTION

Be sure the hot rods are not touched by you or someone else.



13-1. The metal rod.

✔ 13–1. Which rod got hot first?

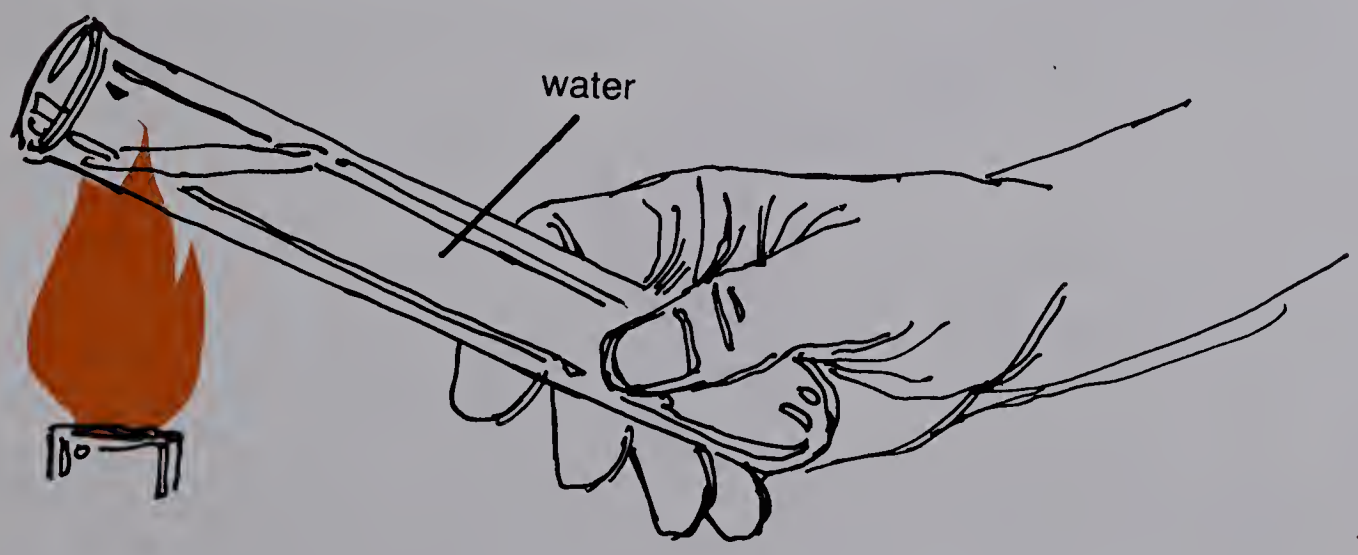
Somehow heat energy passed from one end of the rod to the other. Heat is transferred through a solid by *conduction*. Conduction is a process in which thermal energy is passed from one particle to a neighboring particle. There is no mass motion of the substance, only particle vibrations.

✔ 13–2. What evidence do you have that some particles pass this vibrational energy better than others?

13-2. The metal rod got hot sooner than the glass rod.

In liquids, particles have more freedom for motion than in solids. Would you expect conduction of thermal energy in liquids to be better than in solids? You can find out.

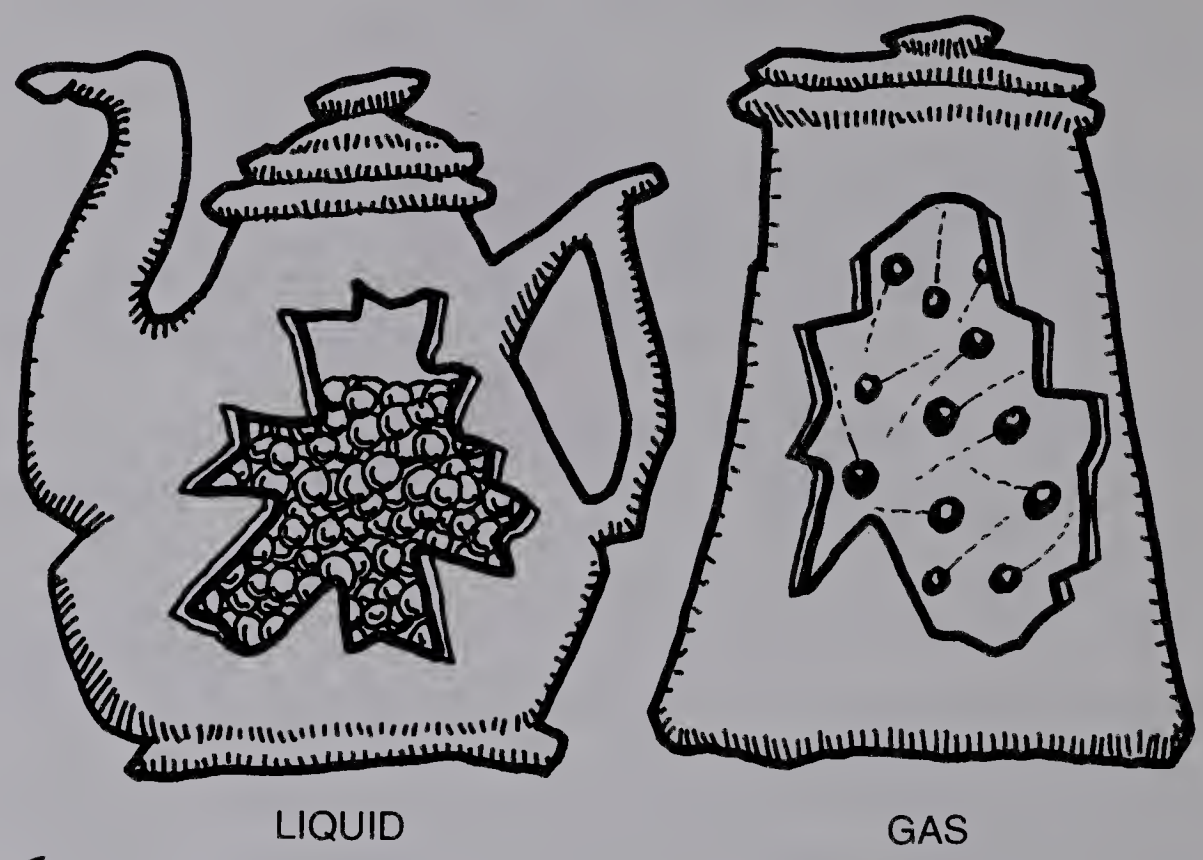
B. Fill a test tube with water within 3 cm of its top. Hold the tube at the bottom in an inclined position, so that the flame of the burner hits the tube just below the water level. Heat until the water at the top of the tube is boiling.



13-3. Water is a poor conductor of heat.

✔ 13–3. Is water a good or a poor conductor of heat?

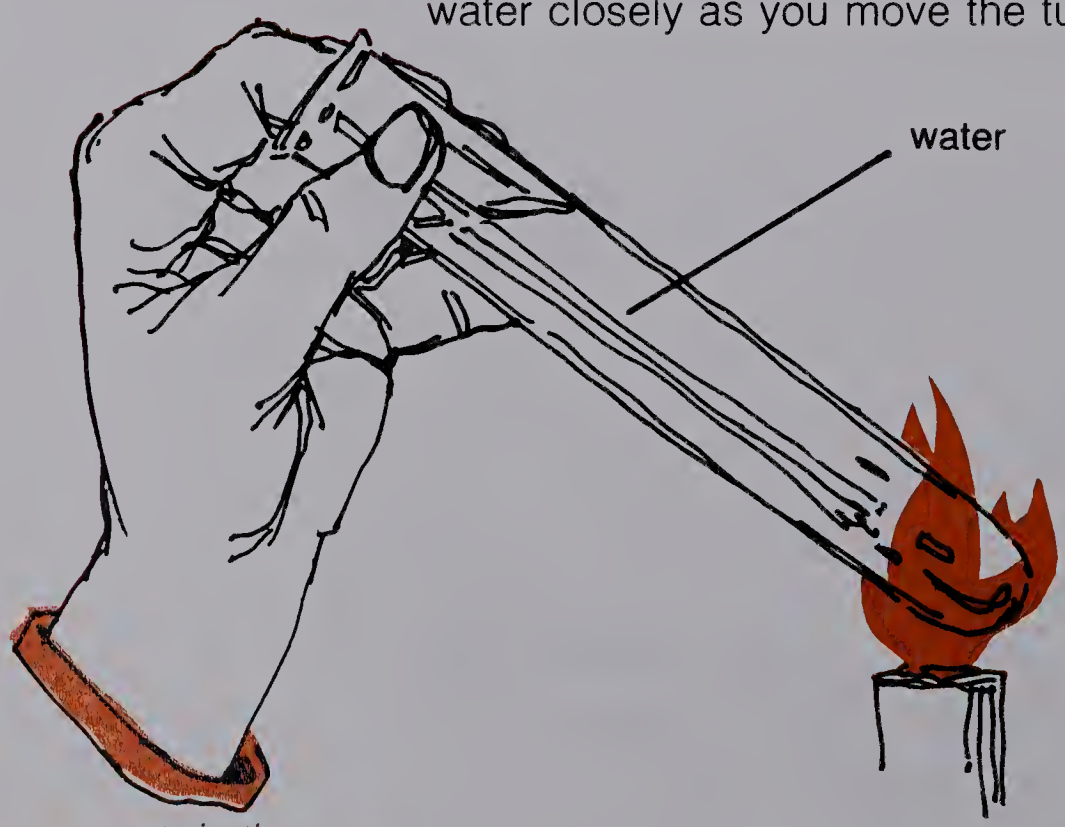
In a liquid, thermal energy is not transferred very well by conduction. Actually, it is transferred by liquids in a different way (and slower) than by solids. In a gas, the particles are farther apart than in a liquid or solid, and there is even less conduction of heat.



13-4. Poor. The molecules are far apart and there are few particle collisions.

✔ 13–4. Would you predict air to be a good or a poor conductor of heat? Explain your answer on the basis of particle collisions.

C. Empty the test tube and refill it with cold water to within 3 cm of its top. This time hold the test tube near the open end in an inclined position, with the flame hitting the bottom of the tube. Move the tube slowly back and forth in the flame. Observe the water closely as you move the tube.

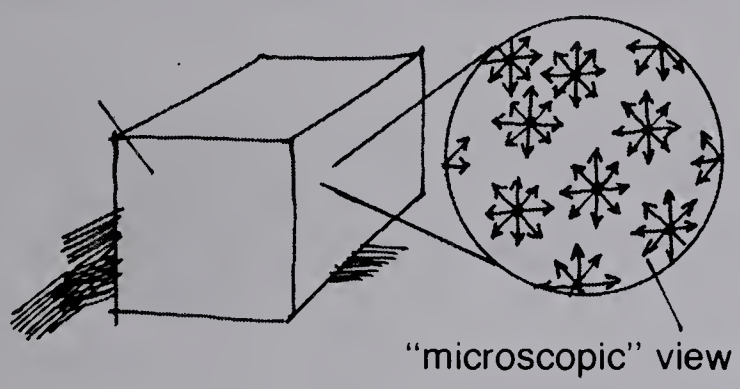


13-5. There were currents in the water and the water at the top of the tube got hot. Heat was transferred rapidly.

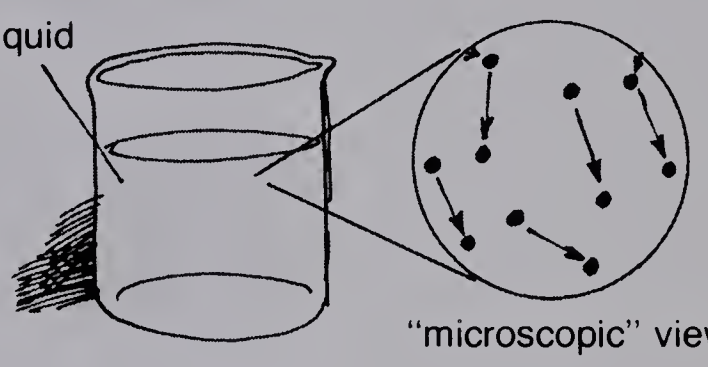
✔ 13–5. Describe your observation of the water and of the transfer of heat.

You know that little heat was transferred by conduction. But you may have seen currents in the water. Heat was transferred by these moving currents of water. The transfer of thermal energy from one place to another by the motion of a mass of heated liquid or gas is called *convection*.

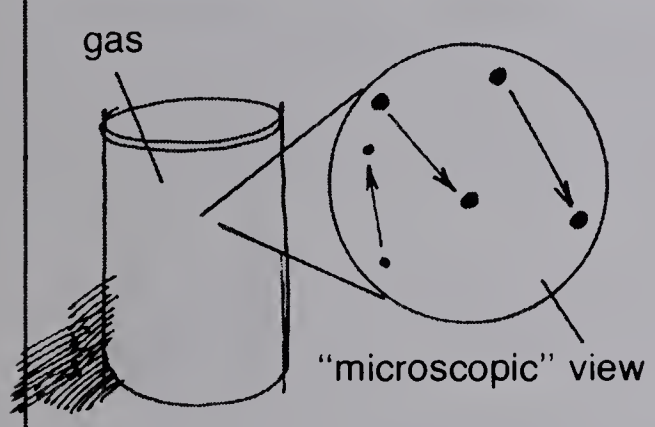
What is the heat or thermal energy that is transferred by conduction or convection? Scientists theorize that it is simply a form of the mechanical or motion, energy of the particles of a substance. This is called the *kinetic molecular theory* and can be summarized as follows:



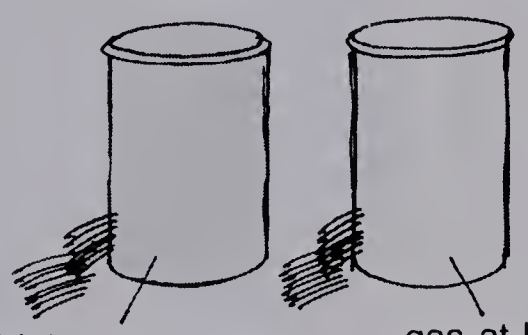
1. In a solid, motion energy consists of small vibrations because the particles cannot move freely in any direction.



2. In liquids, there is freedom of motion of the particles, but they are still close together.



3. In a gas, particles are free to move in all directions.



4. The average energy of the particles is related to the temperature of the substance. The higher the temperature, the greater the average energy of motion.

$$K.E. = \tfrac{1}{2} mv^2$$

5. The energy of motion of the particles is dependent on their velocity, or how fast they move. The kinetic energy of a moving particle can be written K.E. $= \frac{1}{2} mv^2$, where m is the mass of the particle and v is its velocity.

13-6. The mass of the air particles doesn't change, so if the air particles at a higher temperature have more energy, it must be due to greater average velocity of the particles.

★ **13–6. Tell why the average velocity of air particles at a high temperature is greater than that of air particles at a low temperature.**

In the process of heating a room with a stove or radiator, the cold air molecules traveling at a low velocity collide with the hot surface of the radiator or stove. Because the radiator is at a higher temperature than the air, the air molecules leave the stove or radiator with more energy, and a higher velocity.

13-7. Conduction.

★ **13–7. By what process, convection or conduction, is heat energy transferred from a hot radiator to air molecules that collide with it?**

Hot air molecules moving at a higher velocity occupy more space than cold air molecules. This means that hot air is less dense than cold air, and so it rises, like the hot water did in the test tube. As the hot air rises, cold air sinks and comes in contact with the hot surface. This cold air is heated. Thus, heat is transferred to the air, and all the air in the room is heated.

13-8. Mostly convection.

✔ 13–8. By which of the two processes, convection or conduction, is heat energy distributed throughout a room?

Heat energy is transferred by conduction from a hot stove or radiator to air molecules. The heat is distributed throughout the room by convection. When hot air molecules collide with cool walls and windows, they give these surfaces some of their energy by conduction.

ACTIVITY EMPHASIS: Rumford and Davy studied heat caused by friction. Joule and Mayer defined a mechanical equivalent for heat. They all helped refute the caloric theory of heat.



Rumford, Davy, Joule, and Mayer

MATERIALS PER STUDENT UNIT

None.

The title of this activity isn't the name of a law firm, even though it may sound like one. The title is made up of the names of four scientists, each of whom made a contribution to our understanding of heat and helped give us a new theory.

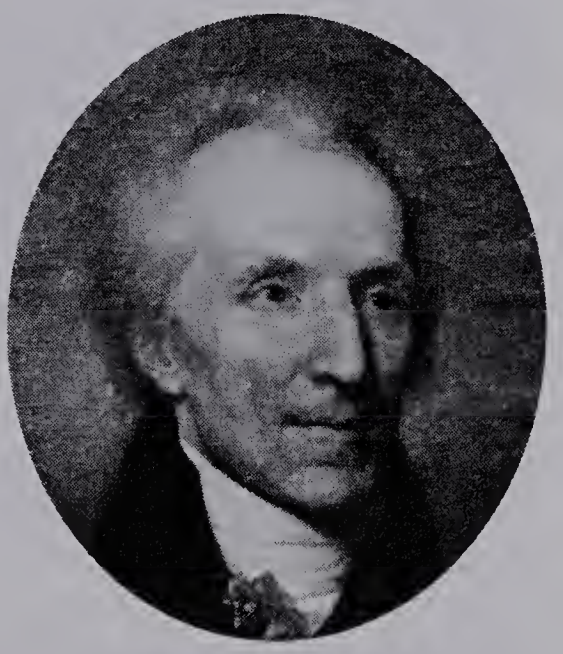
It's hard to describe something that doesn't have physical shape. For instance, you've seen rocks and can tell someone what they look like. But it's hard to describe a force, because you can't see a force. You can only see its effect on something.

Early scientists had a similar problem when they tried to describe heat. They could see its effect on things, but they couldn't see heat. In describing heat, they thought of it as a substance that could flow in or out of an object. They called this heat substance *caloric* [ka-LOR-ik].

The scientists' theory of caloric explained most of the behavior of heat. And many scientists in the mid-1700s were satisfied with the theory. But there were some skeptics. We will look at these doubters in pairs.

The Birth of a New Idea

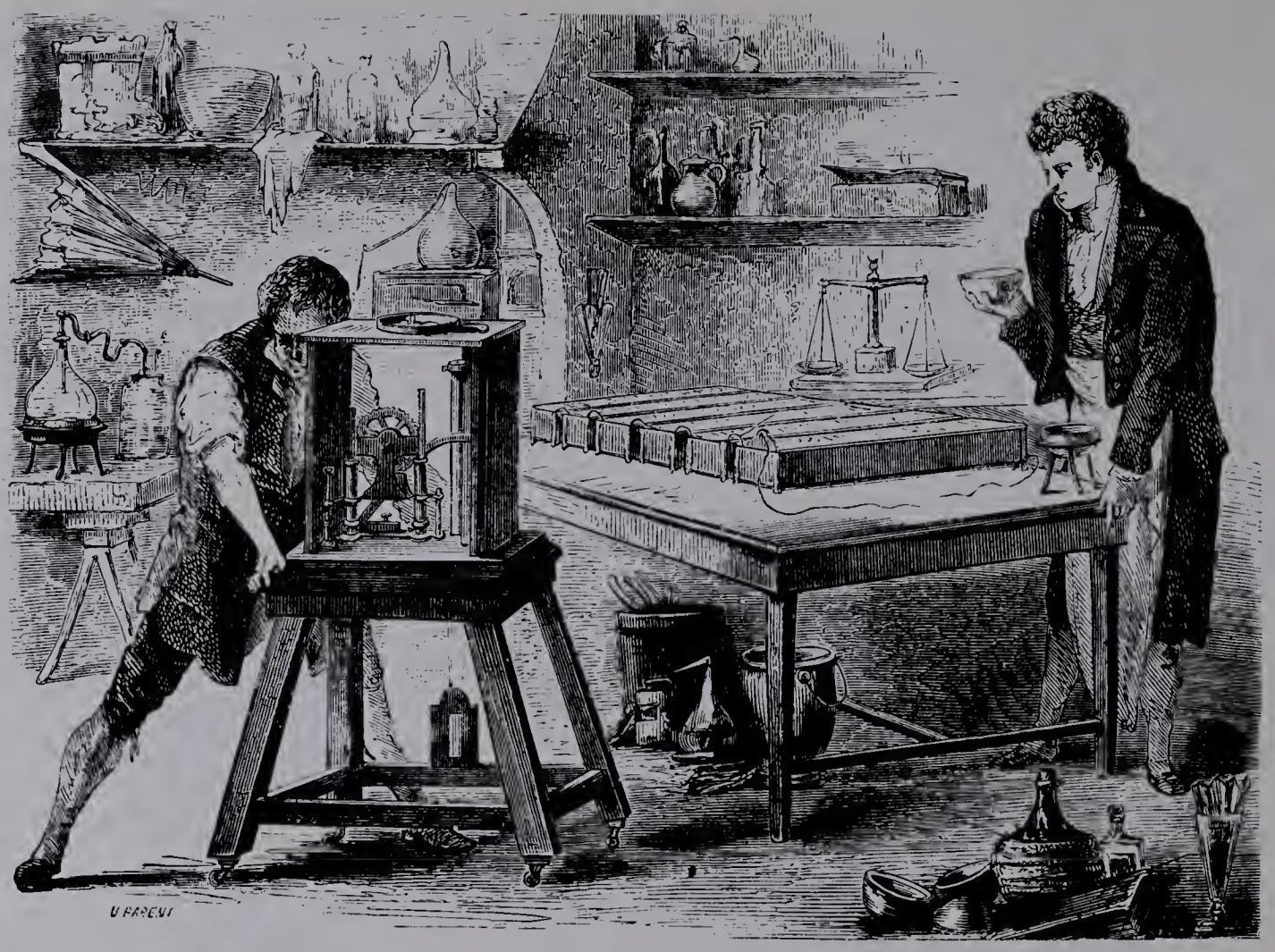
One day in 1798, Count Rumford of Bavaria, born Benjamin Thompson in Woburn, Massachusetts, was supervising the boring of brass cannon in the arsenal in Munich. He was impressed by the large amount of heat given off in the operation. In fact, the supply of heat seemed limitless; it continued as long as the boring tool turned in the metal. Rumford concluded that heat wasn't a substance. There was no such thing as caloric. Instead, he reasoned that heat was due to friction—the mechanical work that was done in boring the cannon.



Portrait of Count Rumford painted by Rembrandt Peale.

A year later, in 1799, a 21-year-old English scholar performed some experiments that further refuted the caloric theory. His name was Humphry Davy. He later achieved fame as a great chemist by discovering the chemical elements barium, boron, calcium, potassium, sodium, and strontium.

Davy set up an apparatus by which he could rub substances together in a vacuum. Using his apparatus he melted ice and wax while their temperatures were below freezing. If the caloric theory were correct, caloric would have been added to the ice and wax in order for them to melt. But where could the caloric come from? Davy concluded that heat must have come from the rubbing action.



Sir Humphry Davy's laboratory

14–1. Both experiments used mechanical work to produce heat. Different substances were used—a cannon and boring tool in one case, and wax and ice in the other.

✔ 14–1. How were the experiments of Rumford and Davy similar? How were they different?

Both Davy and Rumford proposed that heat was a form of motion. Old ideas die slowly, so the caloric theory remained popular for almost fifty years. Joule and Mayer brought on the final death of caloric.

The Death of an Old Idea

James Prescott Joule [JEWL] and J. Robert Mayer were entirely different types of individuals. Joule was a prominent physicist; Mayer an obscure physician. Joule had a superb scientific education; Mayer lacked this advantage. Joule had the ability and the facilities to do experimental work; Mayer had neither. But working independently, each came up with the same assertion—that heat could be converted into mechanical energy, and mechanical energy could be converted into heat.

Joule performed many different investigations in which he converted various kinds of energy into heat. He demonstrated that mechanical energy could be changed into heat in several ways. In one classic experiment, he churned water with paddle wheels turned by falling weights. He made careful measurements of the

amount of work done by the falling weights and the rise in temperature of the water, thus relating mechanical work and heat. After his many experiments, Joule concluded that a one-pound weight falling 772 feet made the temperature of one pound of water rise one degree Fahrenheit. (Notice the English units.)



James Prescott Joule

Without the ability or facilities to experiment, Mayer used a different approach. He applied reasoning to the problem. Mayer, selecting with great acuity from existing experimental evidence, concluded that the warming of a given weight of water one degree Celsius corresponded to a fall of 365 metres by an equal weight of water. (Note the metric units.) Under different circumstances, Joule could have been Mayer, and Mayer could have been Joule.

14–2. By different methods, the Englishman Joule and the German Mayer came to the same conclusion about heat. What was their conclusion?

14–2. That heat resulted from mechanical work.

Modern computations show that Joule's number should be 778 instead of 772, and Mayer's number 427 instead of 365. But the idea was valid. Other scientists who followed added their support to the idea of a mechanical equivalent of heat. The caloric theory was dead and buried for all time.

Mechanical Equivalent of Heat

Mechanical work is measured in newton metres in the metric system. A newton metre is the amount of mechanical work done when one newton of force is exerted over the length of one metre. To get newton metres of work, you multiply the force in newtons by the distance in metres.

newtons × metres = newton metres

14-3. 1 newton metre

✔ 14–3. Suppose an object weighing one newton falls one metre. How much work has been done by the weight?

One newton metre of work is equivalent to one joule of mechanical energy. So a one newton weight falling one metre develops one joule of mechanical energy to turn paddles and churn water.

14-4. 4.184 newton metres or joules

✔ 14–4. If a one newton weight falls 4.184 metres, how much work has been done by the weight?

14-5. 4.184 newton metres or joules

★ **14–5. If an object weighing 4.184 newtons falls one metre, how much work has been done by the object?**

14-6. 4.184 newton metres or joules

✔ 14–6. If an object weighing 8.368 newtons falls 50 cm (one-half a metre), how much work has been done by the object?

Your answers for the last three questions should all be the same (4.184 newton metres or joules). This is the mechanical equivalent of heat that Joule and Mayer defined—that many joules of energy (4.184 joules) will raise the temperature of one gram of water one degree Celsius. That's one calorie of heat energy.

14-7. 1 calorie = 4.184 joules = 4.184 newton metres

★ **14–7. Complete this table of energy equivalents.**

1 calorie = __(?)__ joules = __(?)__ newton metres

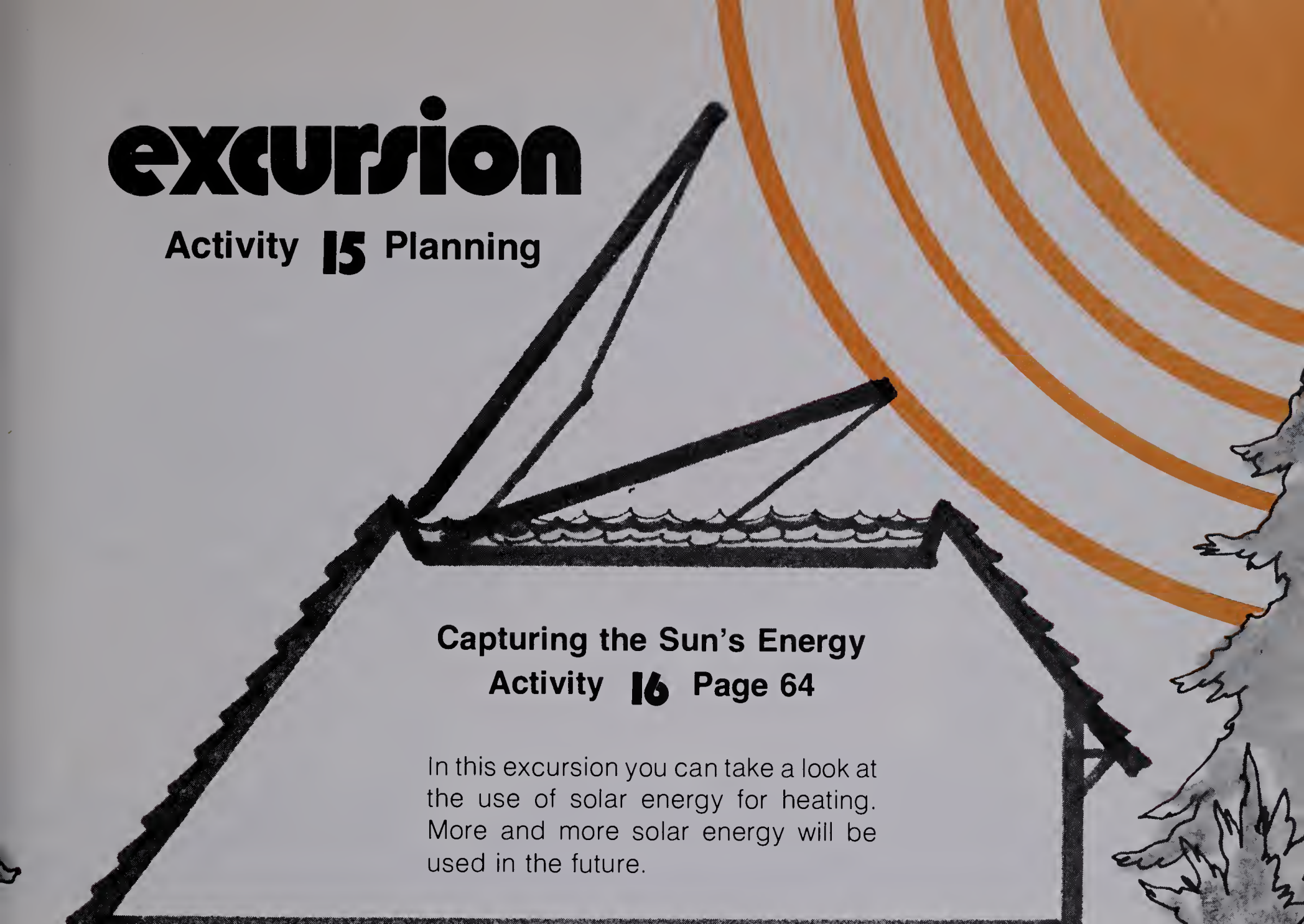
Suppose you had a container that held 1000 g of water. That's 1000 ml, or 1 litre of water. It's a little over a quart. The water is churned by paddles turned by falling weights. Assume all of the mechanical work goes into heating the water.

14-8. 41,840 newton metres or joules

✔ 14–8. How many newton metres, or joules, of energy must be transformed by falling weights to raise the temperature of the 1000 g of water 10°C?

excursion

Activity 15 Planning



Capturing the Sun's Energy
Activity 16 Page 64

In this excursion you can take a look at the use of solar energy for heating. More and more solar energy will be used in the future.

A Penny Saved Is a Penny Earned
Activity 17 Page 69

Everyone should be trying to keep the cost of energy down. Here are some hints on saving money for hot water, refrigeration, and cooking.

Retaining Energy
Activity 18 Page 75

Here's your chance to test an important scientific idea on your own. It's called the "greenhouse effect," and it has important practical applications.

ACTIVITY EMPHASIS: Solar energy can heat buildings and water, and cook food. Electricity produced by solar cells can be stored in batteries.



Capturing the Sun's Energy

All the energy on Earth, except atomic energy has come from the sun. But we make use of only a part of the energy the sun sends. Much energy is reflected back into space.



MATERIALS PER STUDENT UNIT
thermometer, Celsius, 0–110°
foil, aluminum, 3 cm X 10 cm
paper or cardboard, 10 cm X 12 cm
candle
match
tweezers
concave mirror

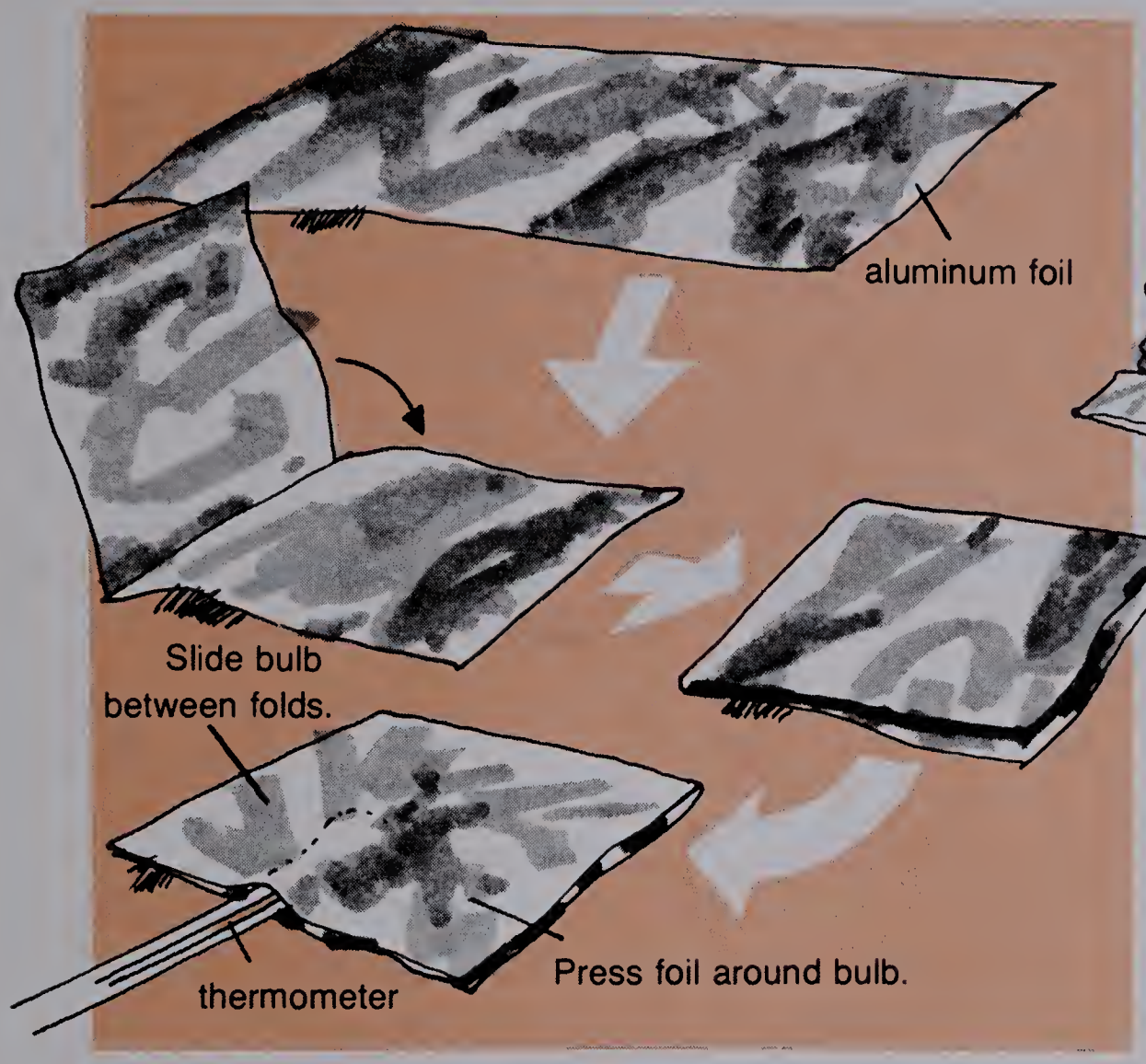
As energy from coal, oil, and natural gas becomes scarcer and more expensive, the idea of using solar energy becomes more attractive. Huge amounts of energy reach Earth every day from the sun. If the solar energy hitting the United States could be captured and used, it would certainly help to make our remaining reserves of coal, oil, and natural gas last longer.

You know that much of the energy used in a home goes for heating devices. It costs to heat your home, heat water, dry clothes, and cook food. If energy from the sun would do some of this heating, you could save money.

But can the sun's energy be captured? The following investigation will give you some idea. You will need about 30 minutes and the following items:

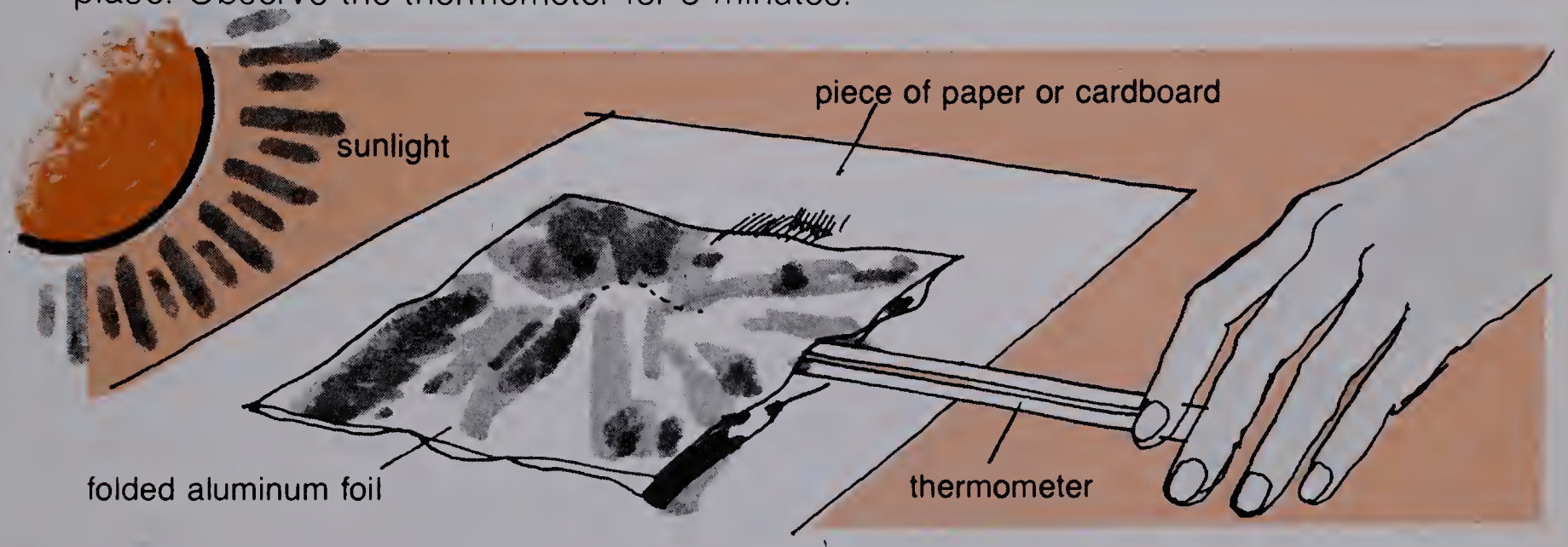
thermometer, 0–110°C
foil, aluminum, 10 cm × 3 cm
paper or cardboard, 10 cm × 12 cm
candle
match
tweezers

A. Fold the piece of aluminum foil into a 5 cm × 3 cm rectangle. Slide the bulb of the thermometer between the folds and press the foil tightly around the bulb.





B. Set the thermometer and foil on a piece of paper or cardboard in *direct sunlight*—on a windowsill or outside in a protected place. Observe the thermometer for 5 minutes.



✓ 16–1. Describe any change in the thermometer.

16–1. The temperature increased a few degrees.

★ **16–2. What happens to most of the solar energy that strikes aluminum foil?**

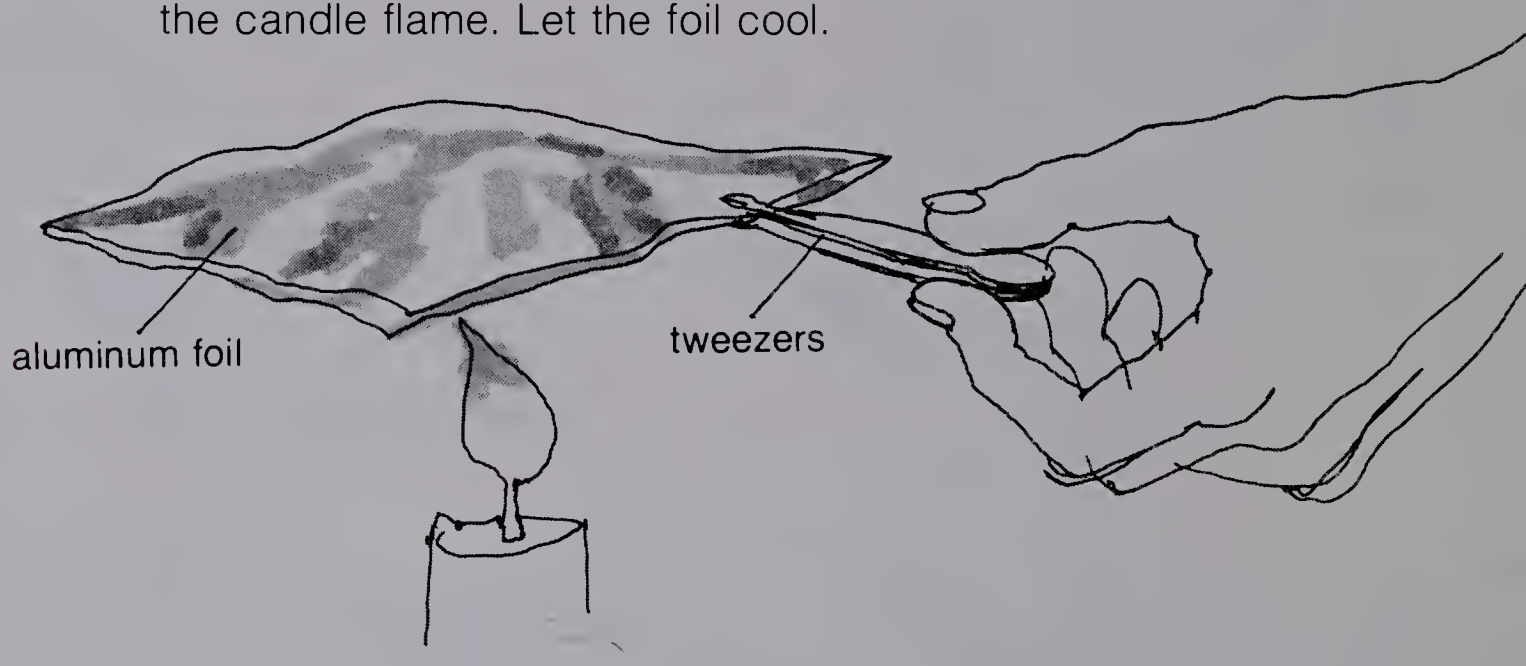
16–2. It is reflected.

Sunlight that isn't captured can't help you very much. Most of the light that strikes the aluminum foil is reflected from the surface. If the foil were a better absorber, more light energy could be captured.

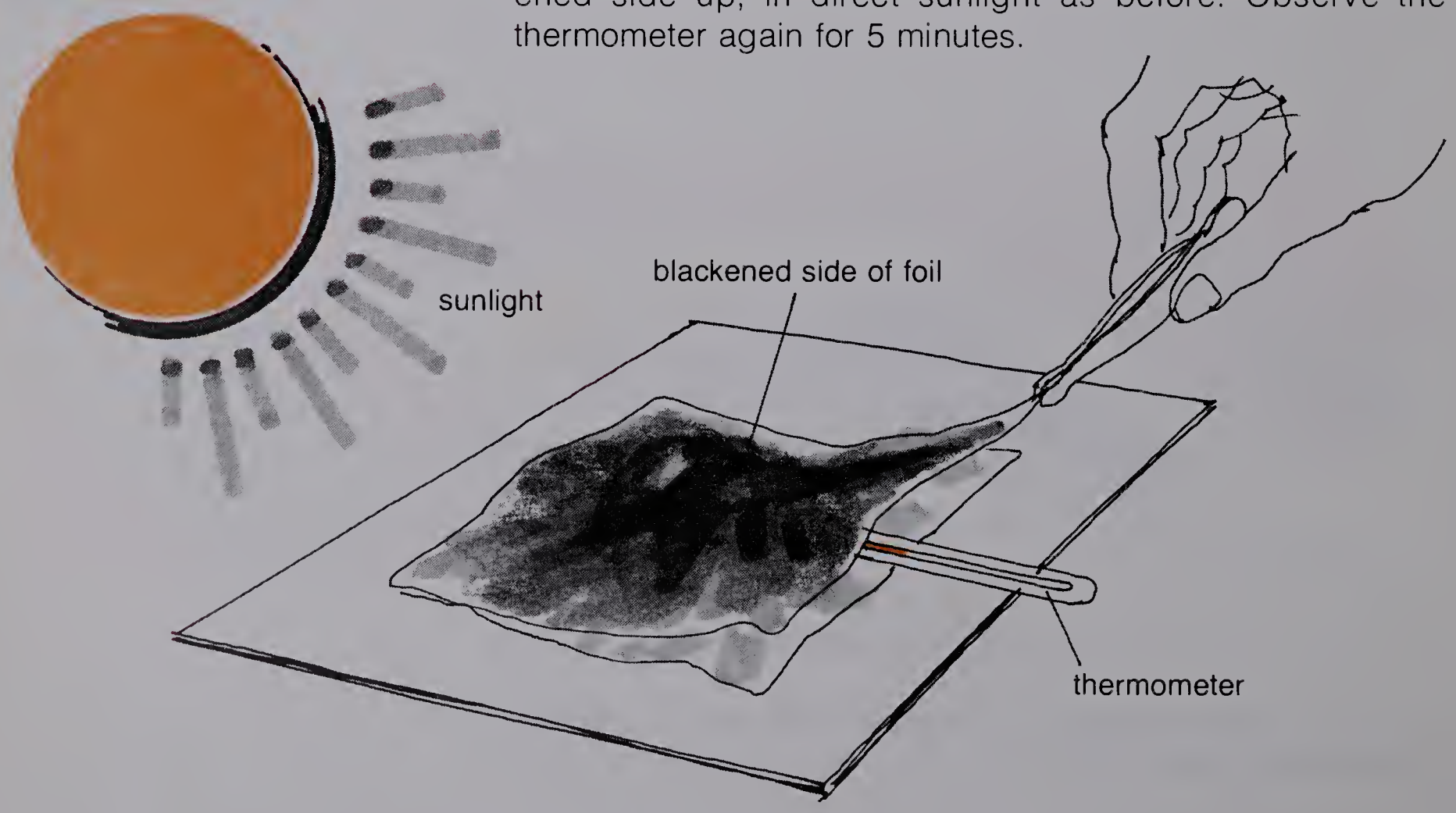
16–3. Blacken it.

✔ 16–3. What can you do to the foil so that it will capture more light energy?

C. *Carefully* slide the foil off the thermometer bulb. Light a candle. Hold the foil with tweezers and blacken one side of the foil in the candle flame. Let the foil cool.



D. *Carefully* slide the foil back over the thermometer bulb. Use the tweezers to press the foil around the bulb. Try not to remove the black soot. Set the thermometer and foil, with the blackened side up, in direct sunlight as before. Observe the thermometer again for 5 minutes.



★ **16–4. In sunlight, how does the change in temperature of blackened foil compare with that of shiny foil?**

16-4. The temperature changed more with the blackened foil.

16–5. Why might a larger heat-absorbing surface capture more energy from the sun?

16-5. More surface area for the sun to strike.

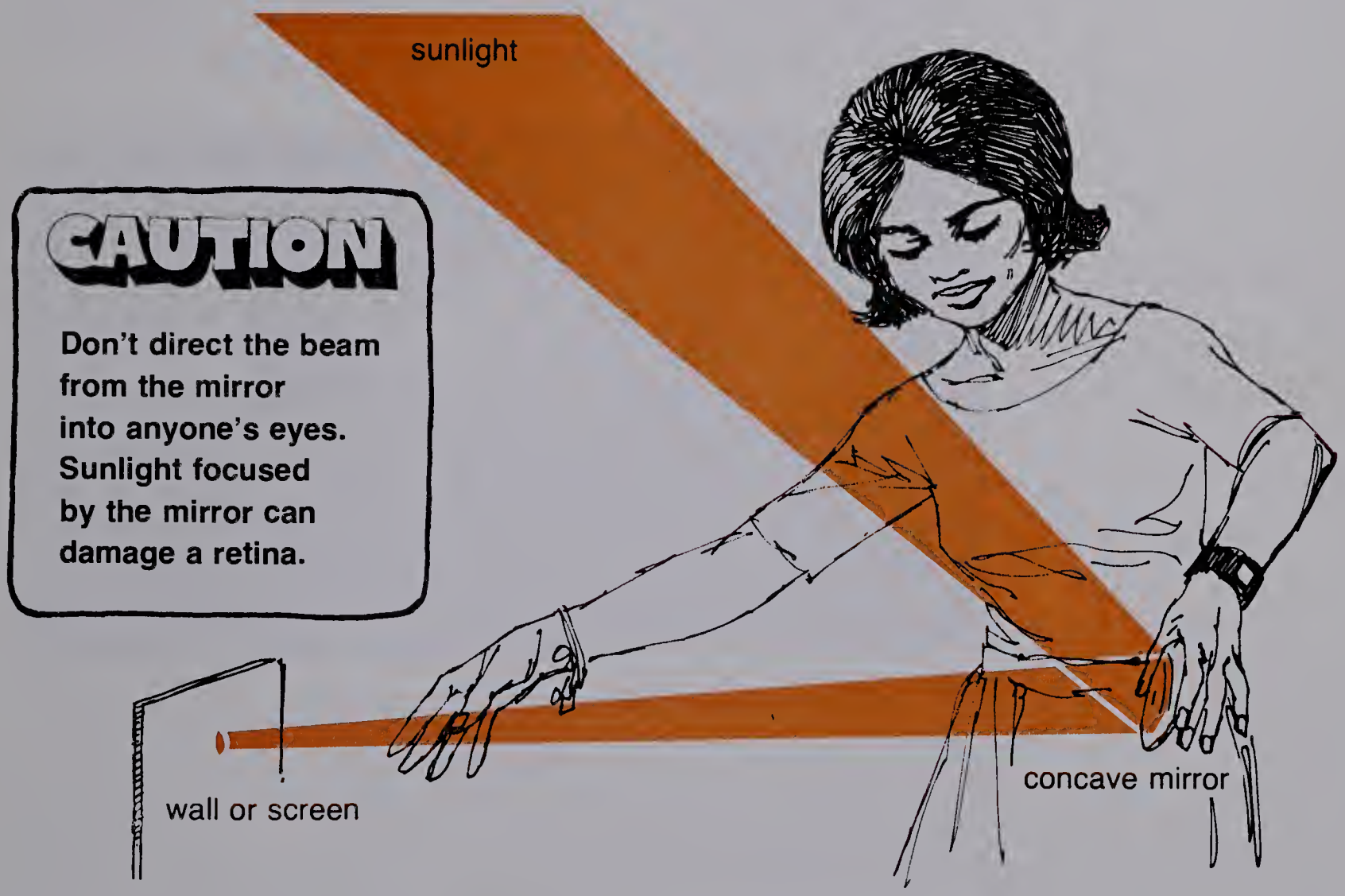
Dark surfaces absorb radiation and change it into heat energy. The energy captured can be used to raise the temperature of water. That's how a solar hot-water heater works. Sun's rays absorbed by a dark surface heat water. The hot water is stored in a tank until needed.

A large solar heater can heat water to over 90°C (194°F). That's plenty hot enough to heat a house, wash clothes, and take a bath. But it's not hot enough for cooking.

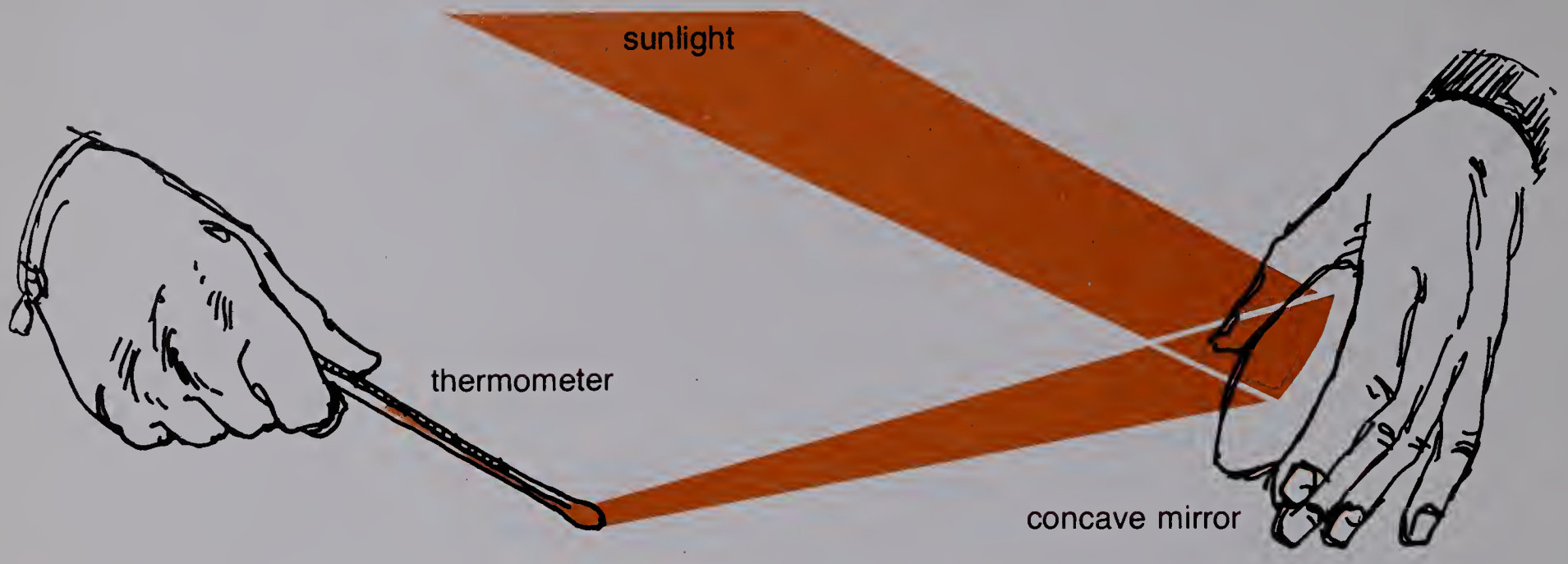
Very high temperatures can be gotten by concentrating the sun's rays. For an idea of how to do this, you will need a few minutes of sunlight and the following materials:

thermometer, 0–110°C
concave mirror

A. Using the mirror in sunlight, focus the sun's rays to the smallest possible spot on a desk top, wall, or screen. Write down the approximate distance from the mirror to the spot.



B. In sunlight, hold the thermometer in one hand and the concave mirror in the other. Focus the bright spot of light onto the thermometer bulb for a minute or so. Read the temperature.

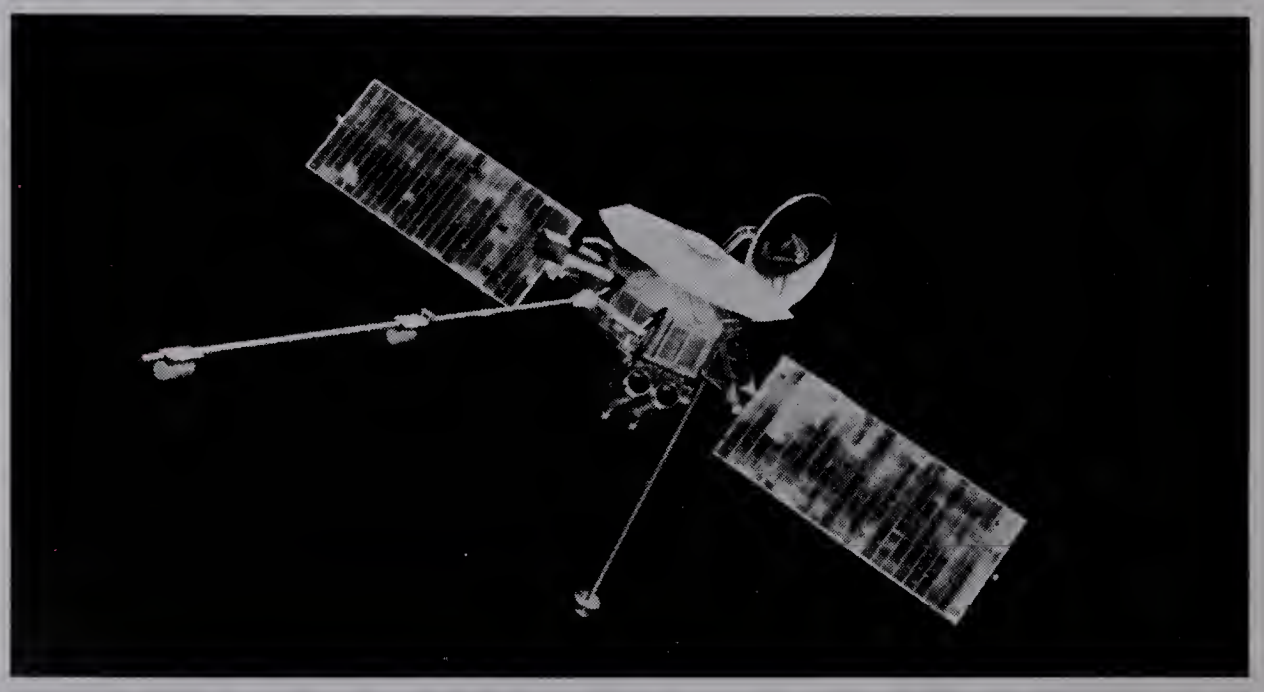


16-6. Answers will vary.

✔ 16–6. What is the temperature change produced by the mirror?

Solar cookers with concave mirrors can boil water and roast meat. They develop temperatures as high as ovens in stoves. Some large solar furnaces will give temperatures high enough to boil iron!

Solar energy can also be captured by solar cells that convert sunlight to electricity. This is the way power is generated for satellites. The electricity can be used right away or stored in batteries.



Electricity for this satellite comes from the solar- cell panels.

16-7. By storing it in batteries during hours of sunlight.

✔ 16–7. How can solar cells provide energy for night use?

As the supply of coal, oil, and natural gas gets less and less, we will be looking more and more to solar energy. There's plenty of it, and it's free.

ACTIVITY EMPHASIS: Wasting electricity wastes money. Hints are given for using electric stoves, refrigerators, and water heaters efficiently.

A Penny Saved Is a Penny Earned



When money is saved in household energy, it's usually done a penny at a time. Apart from heating or cooling your home, most energy is used by the hot-water system, refrigerator, and the cooking stove. So let's take a look at how you can save energy with these three appliances.

MATERIALS PER STUDENT UNIT

saucepan, 15-cm (6-inch) diameter
adhesive tape or grease pencil
watch with second hand

Hot-Water System

The storage tank in a hot-water system can be insulated so it doesn't lose heat rapidly. But the pipes leading from the tank are rarely as well insulated. So hot water in the pipes cools off. This wastes heat, as Figure 17–1 shows.

HOW HEAT IS WASTED

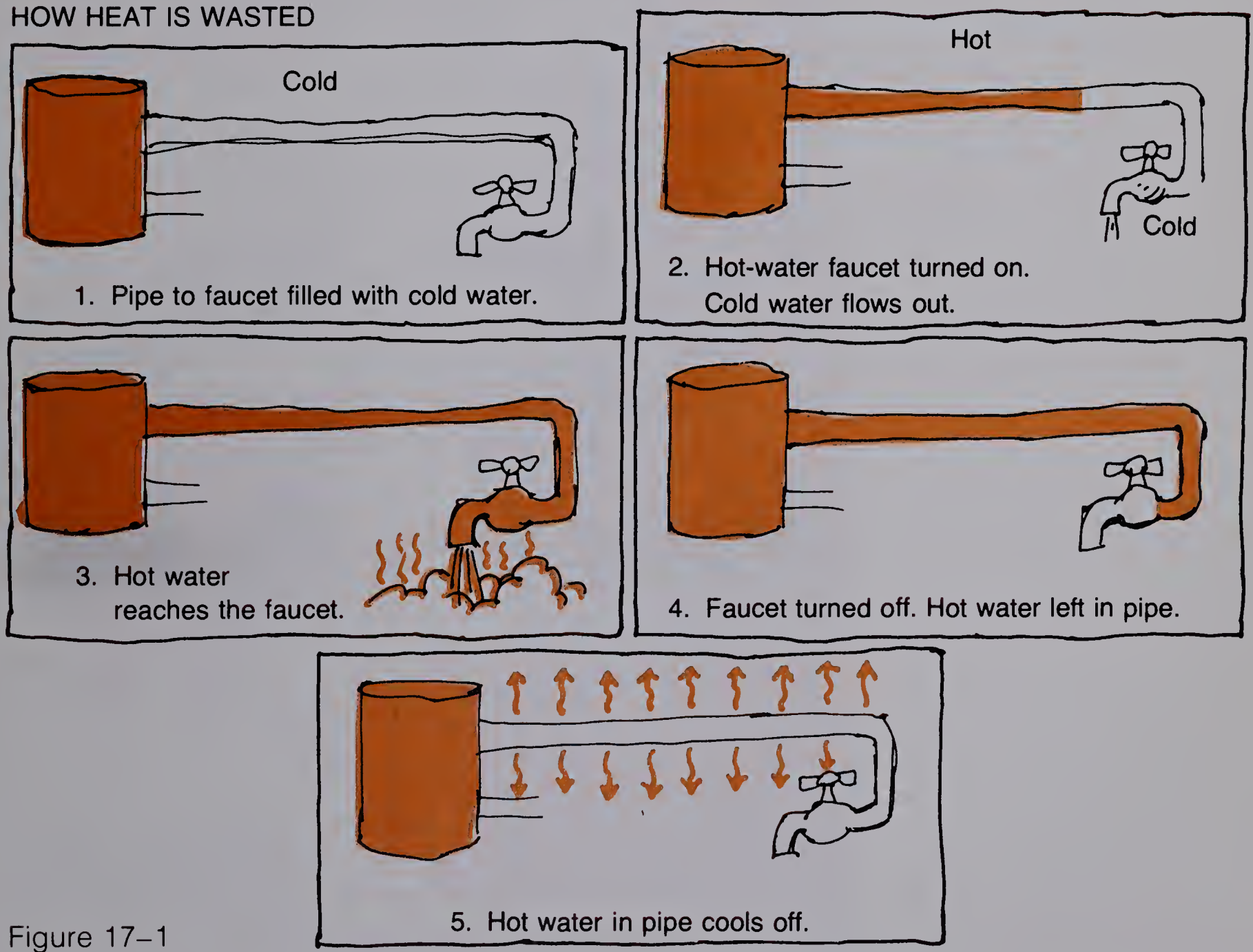


Figure 17–1

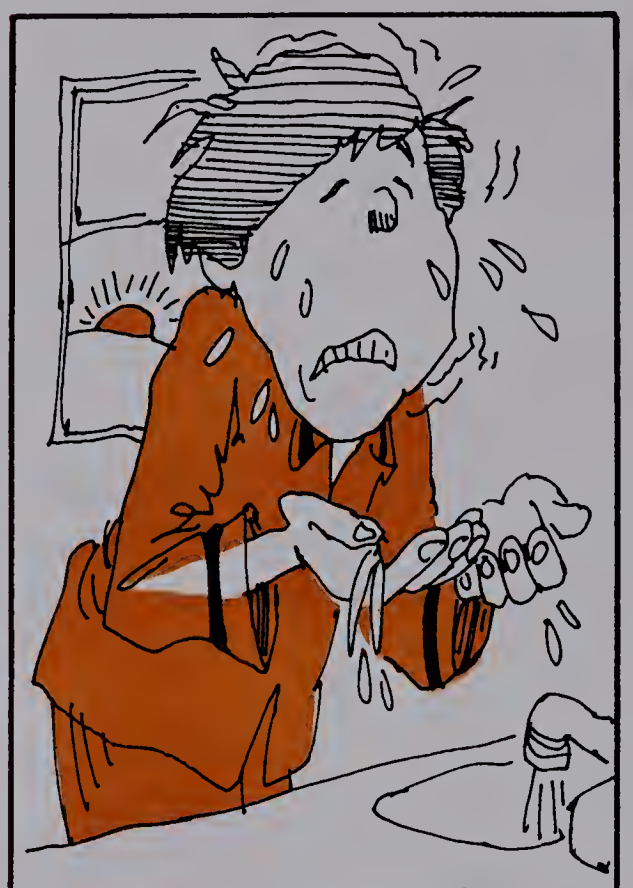
17-1. Goes into the air in the house.

17-2. The air conditioner would run more.

✔ 17–1. What happens to the heat from the hot pipes?

✔ 17–2. What effect might this have on an air-conditioning system in the summer?

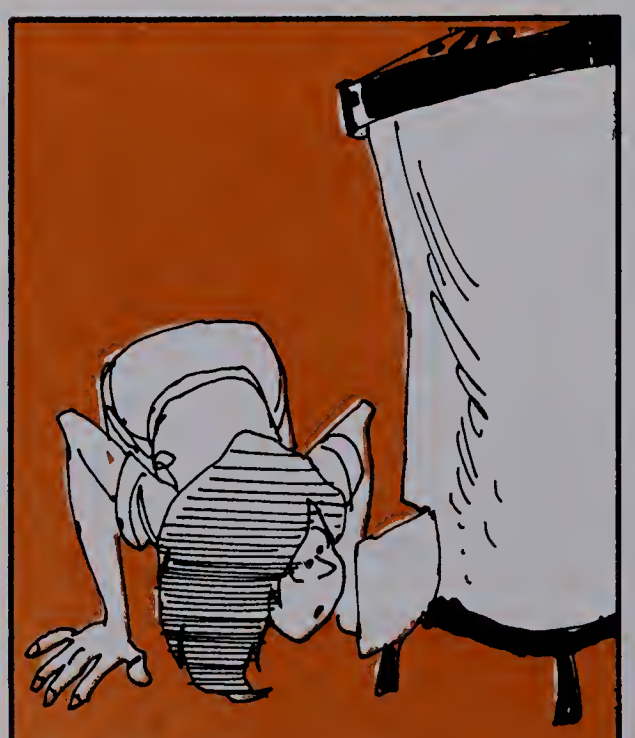
HINTS ON SAVING ON HOT-WATER HEATING



1. Use cold water whenever you can.



2. Set bath times as close together as possible.



3. Set the thermostat as low as possible. A setting between 60°C and 66°C (140°F and 150°F) is usually high enough.



4. Repair leaky faucets as soon as possible.

17-3. Water in the pipes doesn't have time to lose heat.

✔ 17–3. How does Hint 2 save hot water?

✓ 17–4. How does Hint 3 save energy? (Refer to Activity 7 if you're not sure.)

17-4. The higher temperature of the water, the greater the heat loss from the pipes.

★ **17–5. Water dripping from a leaky hot-water faucet may be quite cold. How then, does it save energy to stop it from dripping?**

17-5. It stops the flow of hot water from the heater into the pipes.

Refrigerator

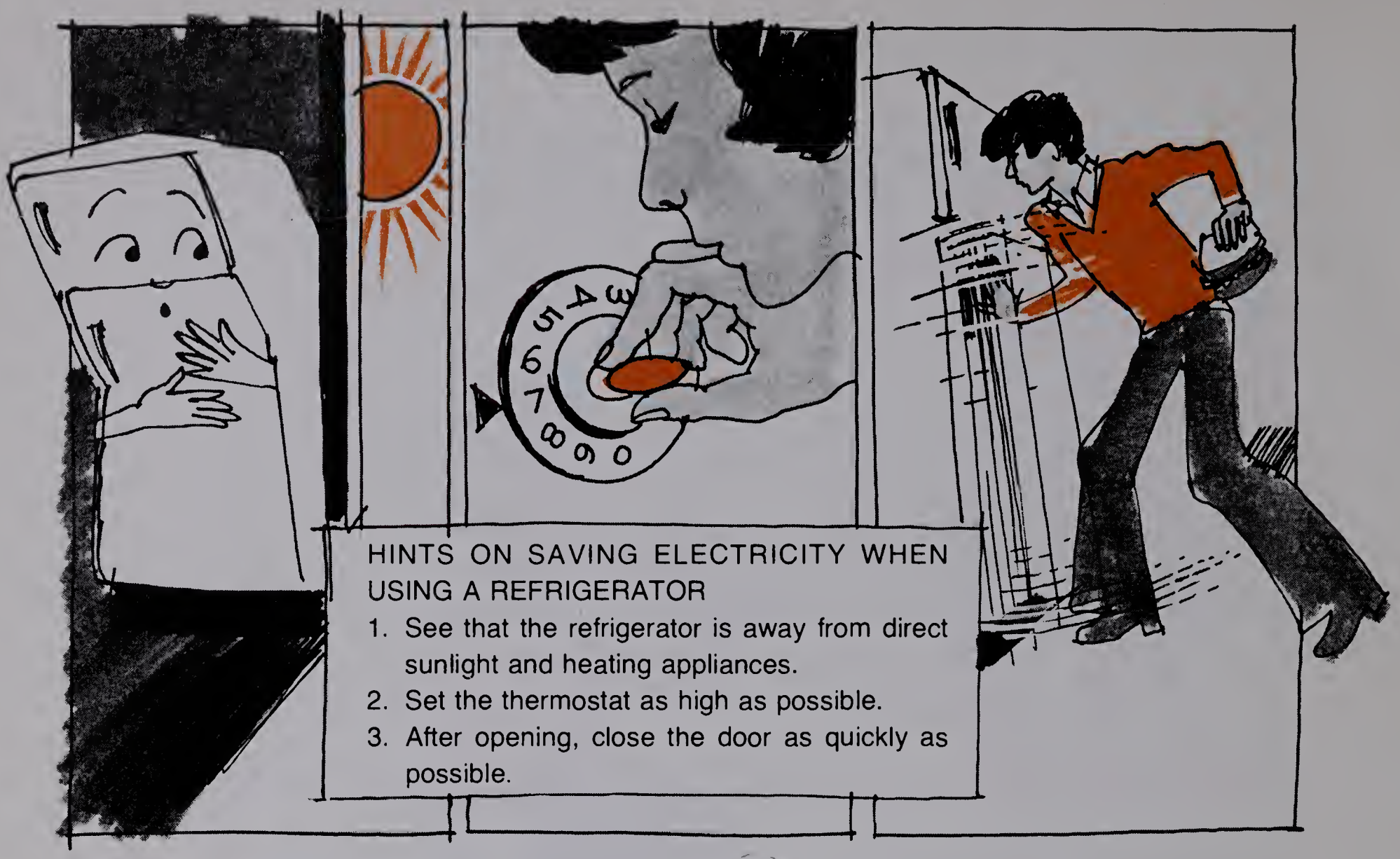
A frost-free refrigerator uses 39–50% more electricity than a regular refrigerator. So you pay for the convenience of not having to defrost your refrigerator.

A refrigerator is insulated to stop heat from getting in and cold air from flowing out. The rubber or plastic seal on the door is very important. If the seal isn't tight, the refrigerator motor will have to run longer.

You can check to see if the seal in your refrigerator should be replaced. Here's how to do it.



Close the refrigerator door on a piece of paper about the size of a dollar bill. Try to pull it out. Repeat the test at five or six different places around the seal. If you find any spot where the paper slides out easily, the seal should be replaced.



17-6. Because the refrigerator is the opposite of a hot-water heater—it cools instead of heats.

✔ 17–6. Why does Hint 2 for the refrigerator say the opposite of Hint 3 for the hot-water system?

Electric Stove

Most electric stoves have heating elements of different sizes. Usually, there is a 20-cm (8-inch) element that uses about 4000 watts and a 15-cm (6-inch) element that uses about 2500 watts.

Electricity is wasted when you use a bigger element than is needed. If you use the 20-cm element to heat a 15-cm pot, some of the heating element won't be under the pot. Here is a simple investigation you can try. You will need the following:

saucepan, 15 cm (6-inch) diameter
adhesive tape or grease pencil
clock or watch with second hand

You may prefer to have students do this investigation at home.

A. Copy the table in Figure 17–2 in your notebook. Be sure the saucepan just covers the 15-cm (6-inch) element of the stove. Use the adhesive tape or grease pencil to mark the saucepan about ⅓ up on the inside. Fill the saucepan with cold water until the water is exactly level with the mark.



B. Turn the 15-cm element to its highest setting. In your table, write the number of seconds it takes for the water to come to a vigorous boil.



ELECTRICITY USED BY A STOVE

	WATTAGE	TIME (IN SECONDS)	WATT SECONDS
15-cm element	2500		
20-cm element	4000		



Figure 17–2



C. Empty the saucepan and cool it under water from the faucet. Then refill it with cold water to the same mark as in Step A. Place it on the 20-cm (8-inch) element. Turn the element to its highest setting. Time how long it takes for the water to boil vigorously. Record this time in your table.

✔ 17–7. Calculate the watt seconds of electricity by multiplying wattage by seconds. Fill in the third column of the table.

17-7. Answers will vary.

✔ 17–8. Which element used more electrical energy to bring the same amount of water to boiling?

17-8. The larger element.

★ **17–9. Why does it take more electrical energy to bring the same amount of water to a boil on a burner that is larger than the pan than on a burner just as large as the pan?**

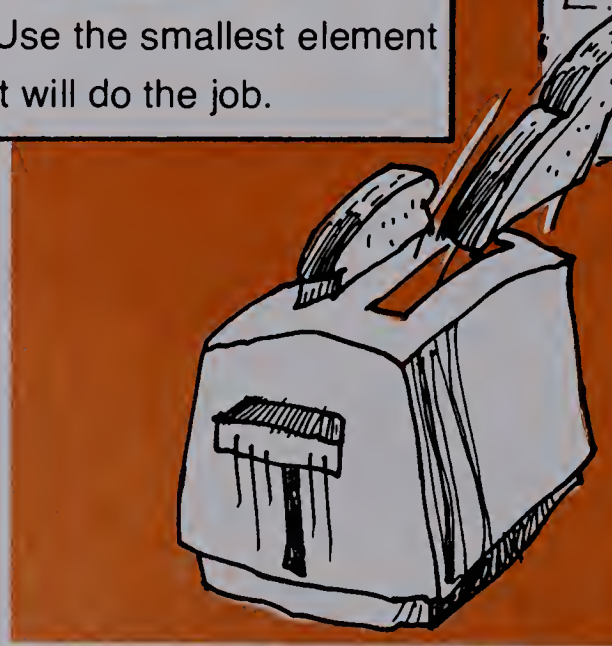
17-9. Because a lot of the energy is wasted.

HINTS ON SAVING ELECTRICITY WHEN USING AN ELECTRIC STOVE

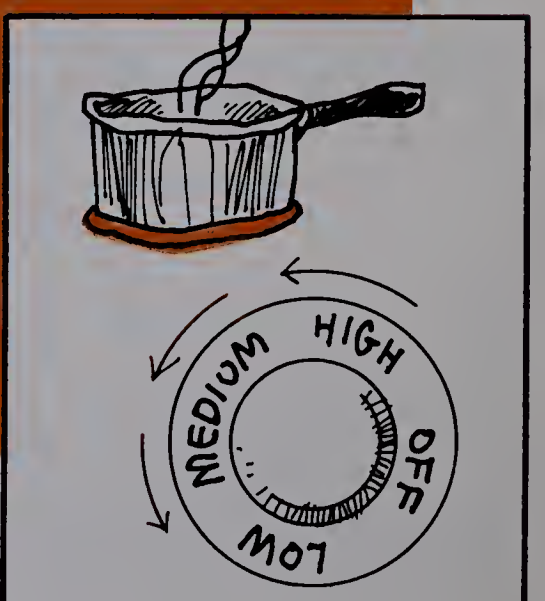


1. Use the smallest element that will do the job.





2. For small cooking jobs (making toast), use a smaller appliance (a toaster) rather than a larger one (the oven).



3. Turn down the element as a liquid nears boiling.

ACTIVITY EMPHASIS: Greenhouse effect allows light to pass through glass or plastic easily while heat is trapped.

Retaining Energy



MATERIALS PER STUDENT UNIT
plastic foam cup
thermometer, Celsius, 0–110°
plastic wrap

A dark or dull surface is a better energy absorber than a light or shiny one. For capturing energy, there's just one trouble with a dark surface. A good absorber is also a good radiator, so the dark surface gives energy away almost as fast as it gets it.

But there's a way of keeping the energy. It makes use of an interesting scientific principle called the *greenhouse effect.* It is illustrated in Figure 18–1.

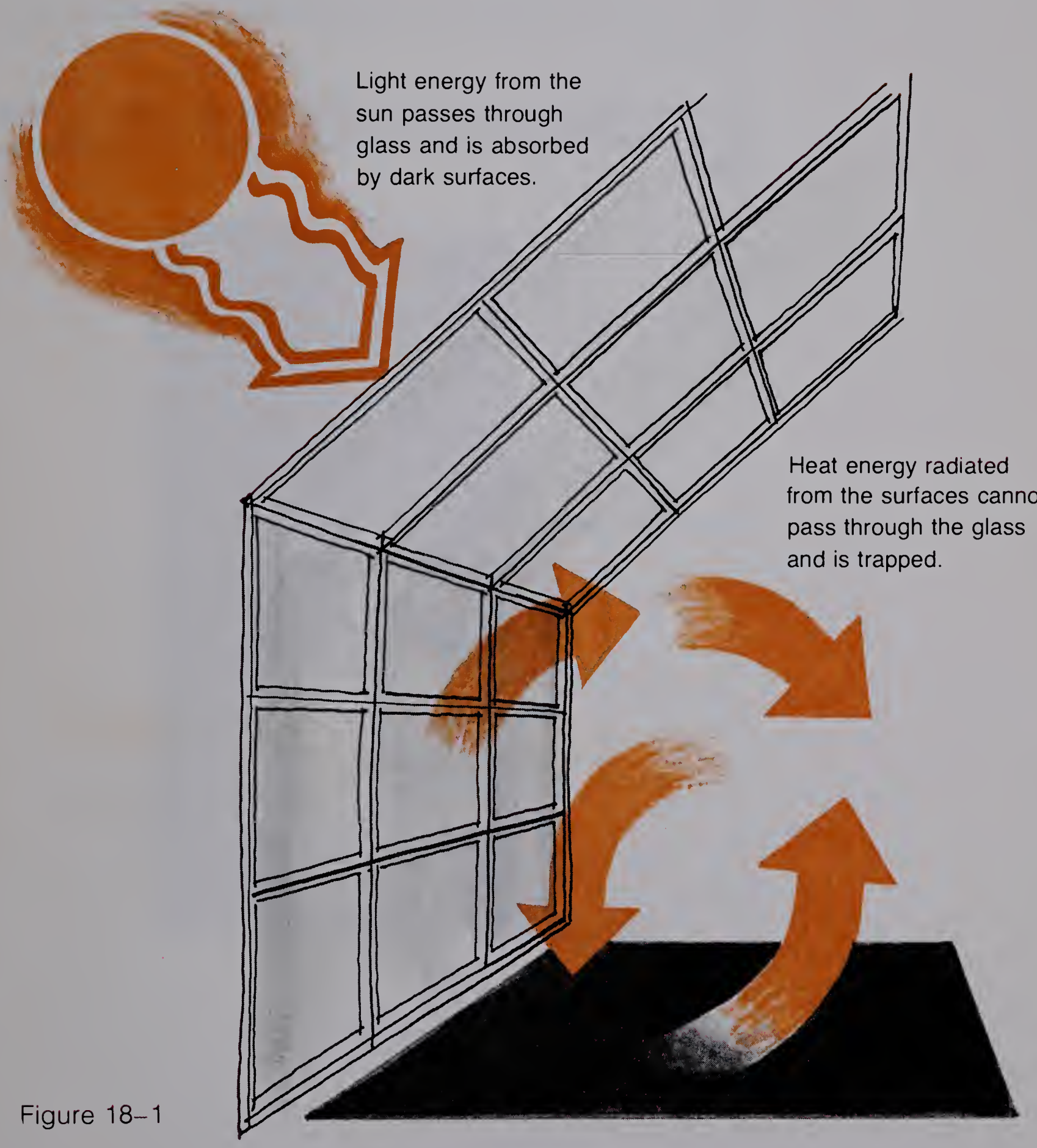


Figure 18–1

18-1. Light.

★ 18–1. Which passes more easily through glass, light or heat?

You can show how glass or plastic can help keep heat energy. A plastic foam cup, a thermometer, a piece of plastic wrap, and some sunlight are all you need. Set up the investigation and then answer the following questions.

18-2. Answers will vary. (I pushed the thermometer bulb through the side of the styrofoam cup and set it in direct sunlight for 5 minutes and read how much the temperature went up. Then I covered the top of the cup with clear plastic and set the cup in direct sunlight for 5 minutes again and read how much the temperature went up.)

✔ 18–2. Briefly describe the procedure you used.

18-3. It kept the heat in much better.

✔ 18–3. How well did the plastic keep heat energy from escaping?

★ 18–4. How do you think the fact that light goes through glass easier than heat does got to be called the greenhouse effect?



18-4. Greenhouses are kept warm in cool weather by light coming through the glass, hitting the plants and earth and changing to heat energy. The heat is trapped and can't get back out through the glass.

For many years, it was thought that greenhouses were kept warm by trapped infrared radiation. Now, it is known that the heating results because the roof stops convection currents from carrying the heat away from the greenhouse. However, the term "greenhouse effect" is still used to indicate the trapping of infrared radiation by a layer of CO_2 in the atmosphere.

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